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WESTERN CONIFERS RESEARCH COOPERATIVE

1987 RESEARCH PLAN

by

Richard K. Olson
Northrop Services, Inc.
200 S.W. 35th St., Corvallis, OR 97333

National Acid Precipitation Assessment Program

U.S. Environmental Protection Agency

U.S. Department of Agriculture -- Forest Service

National Council for the Paper Industry for Air and Stream Improvement

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Summary

The Western Conifers Research Cooperative is part of the national Forest Response Program (FRP). The FRP is a federal program designed to determine the current and potential effects of atmospheric deposition on forests in the United States. Research is conducted regionally within four research Cooperatives. The Western Cooperative is concerned with the effects of atmospheric deposition on coniferous forests in the eleven conterminous western states.

An annual research plan is the foundation of each Cooperative's research effort. The research plan describes the Cooperative's objectives, the overall plan for achieving the objectives, and the specific projects to be implemented. Development of a plan ensures that individual projects are integrated within the Cooperative. Review of the plan by the FRP Synthesis and Integration Group ensures that each Cooperative's research is integrated with the research conducted by the rest of the FRP.

The 1987 Research Plan of the Western Cooperative was developed with the assistance of a large number of western scientists. Input was received from workshops and from comments received on a draft Plan distributed to over 100 persons in August 1986. A formal peer review and reviews by the FRP Quality Assurance staff and Synthesis and Integration Group completed the process.

The 1987 Research Plan first outlines the objectives and research strategy of the FRP. The objectives and strategy of the Western Cooperative are then described in the context of the parent organization. The 1986 Western Cooperative program is reviewed followed by a description of the 1987 program. Brief descriptions of each of the individual 1987 research projects are also given.

In addition to its role in guiding the development and implementation of the Cooperative's research effort, the 1987 Research Plan has other functions:

-- To provide a general source of information about the Cooperative. Many people have assisted in planning the Cooperative and are interested in seeing the result.

-- To inform directors of related programs about possibilities for collaboration.

-- To help prospective investigators to fit their proposals within the integrated framework of the Cooperative.

-- To generate new ideas. The FRP is constantly evolving as new information is accumulated. It is unlikely that there will ever be a truly "final" research plan.

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The 1987 Research Plan is not a Request for Proposals (RFP). RFPs will be issued separately for each project to be implemented by that procedure. Notification of RFPs will be made through advertisement in the Commerce Business Daily and through the Western Cooperative mailing list. Persons wishing to be added to the mailing list or to comment on the Research Plan should contact:

Richard Olson
Director
Western Conifers Research Cooperative
200 S.W. 35th Street
Corvallis, Oregon 97333
(503)757-4600
FTS 420-4600

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1.0 Introduction

The Western Conifers Research Cooperative (WCRC) is a research program charged with investigating the effects of acid deposition and associated pollutants on coniferous forests in the western United States (WA, OR, CA, NV, ID, UT, AZ, NM, MT, WY, CO). The Cooperative is administered by the U.S. Environmental Protection Agency at the Environmental Research Laboratory -- Corvallis (OR).

The WCRC is part of the Forest Response Program (FRP), a national program concerned with issues of air quality and forest health. The FRP in turn is part of the National Acid Precipitation Assessment Program (NAPAP). It is important to be aware of this organizational structure because the goals of these parent organizations define the objectives of the WCRC. The Cooperative's research program can be evaluated only in the context of a larger integrated effort.

For this reason, the next sections will give a brief description of NAPAP followed by a more detailed description of the Forest Response Program. The objectives of the FRP will be emphasized as will the strategy developed to meet those objectives. Finally, the research program developed for the WCRC in support of the FRP strategy will be discussed. This will include an overview of the 1986 research program followed by a description of the 1987 research program.

The term "atmospheric deposition" is used throughout the Plan. It is synonymous with "acidic deposition, alone or in combination with other pollutants (e.g., SO_x, NO_x, metals, O_3, H_2O_2, or hydrocarbons)."

2.0 NAPAP

The National Acid Precipitation Assessment Program (Fig. 1) is a federal interagency effort. The goal of NAPAP is to conduct research on and develop assessments of the environmental impacts of acid rain to provide a firmer scientific basis for decisions by legislators and regulatory officials. Since policy-makers with concerns about regulation of sulfur and nitrogen emissions are NAPAP's main clients, the program places primary emphasis on these compounds.

NAPAP research is conducted by seven Task Groups (Fig. 1), each of which concentrates on a particular aspect of the problem. Research on the terrestrial effects of acid deposition is planned and managed through Task Group V, Terrestrial Effects. Members of Task Group V include the U.S. Forest Service, U.S. Environmental Protection Agency, U.S. Department of Energy, Cooperative States Research Service (U.S.D.A.), National Park Service, and the U.S. Geological Survey.

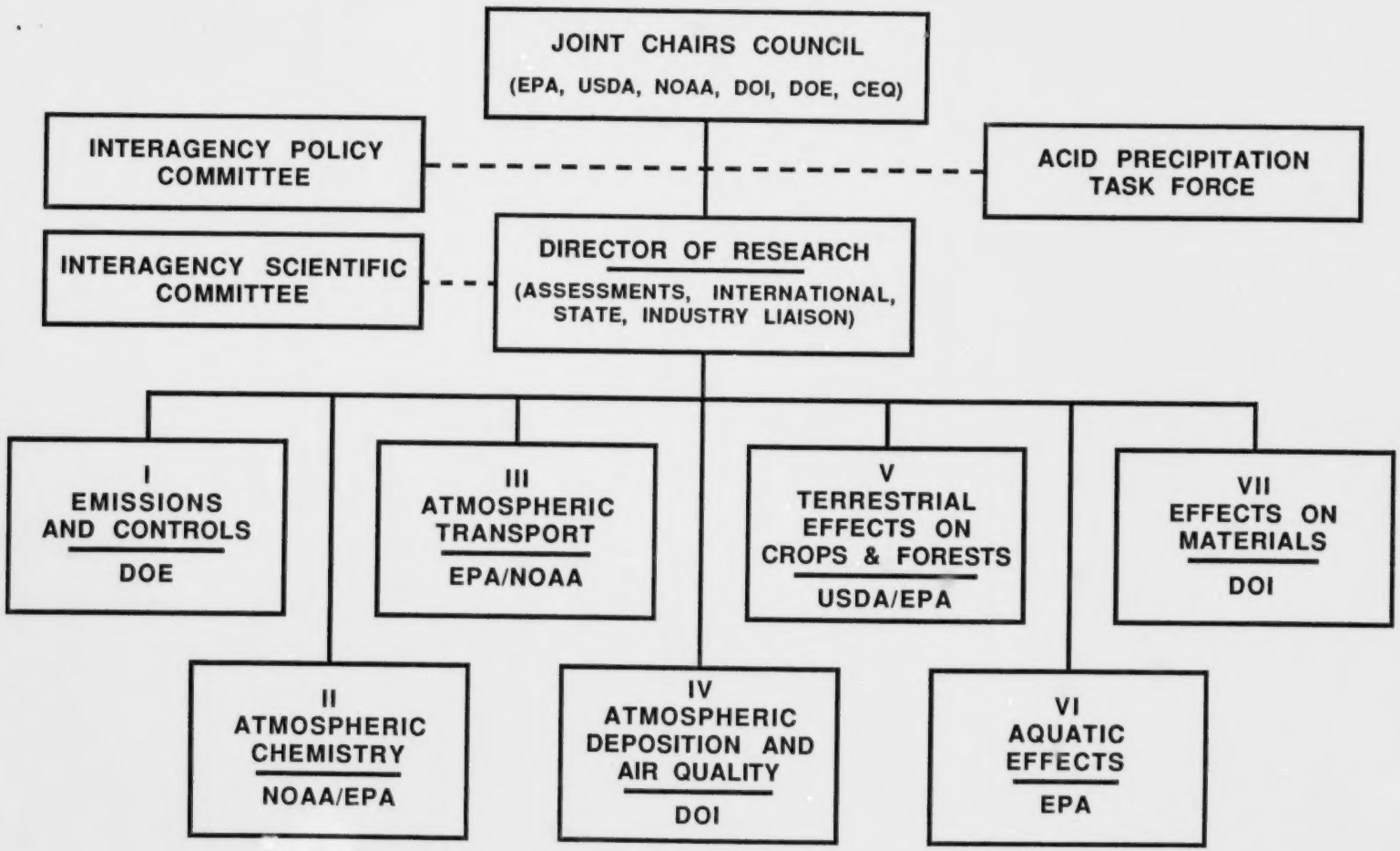

Fig 1. NAPAP organizational chart.

3.0 Forest Response Program

3.1 Administration and Objectives

The Forest Response Program conducts research for Task Group V on the effects of acid deposition and associated pollutants on forests in the United States. The FRP is administered and funded jointly by EPA and the U.S. Forest Service and receives financial and technical support from the National Council of the Paper Industry for Air and Stream Improvement (NCASI).

The objective of the FRP is to provide information that can be used to address three broad questions related to environmental policy. The three policy questions are listed below.

Policy Question 1: Is there a significant problem of forest damage in North America which might be caused by acidic deposition, alone or in combination with other pollutants (e.g. SO_x, NO_x, metals, O_3, H_2O_2, or hydrocarbons)?

Policy Question 2: What is the causal relationship between acidic deposition, alone or in combination with other pollutants, and forest damage in North America?

Policy Question 3: What is the dose-response relationship between acidic deposition, alone or in combination with other pollutants, and forest damage in North America?

Although sulfur and nitrogen are of primary interest to the FRP, the pollutants of concern have been expanded beyond "acid rain" to include oxidants, metals, and organic compounds. Many of the hypothesized mechanisms of forest damage which have been developed in Europe and the U.S. involve pollutant interactions.

In addition, detecting deviations from normal forest condition caused by a particular pollutant(s) requires a definition of "normal." This involves determining the influence of natural factors and other pollutants on the forest as part of the assessment of the effect of the pollutant of primary interest.

3.2 Organizational Structure

The organizational structure of the FRP is shown in Figure 2. Oversight is provided by the four person Federal Management Group (FMG). The National and Deputy National Program Managers are responsible for developing and managing the total research program. Names of all FRP managers are given in Section 10.

Because of regional differences in forests and pollutant regimes, FRP research is conducted within four administrative regions corresponding to major forest types: spruce-fir, southern commercial, eastern hardwoods, and western conifers. Additional research as well as support for the four regional Cooperatives is provided by the Atmospheric Exposure Cooperative and the National Vegetation Survey.

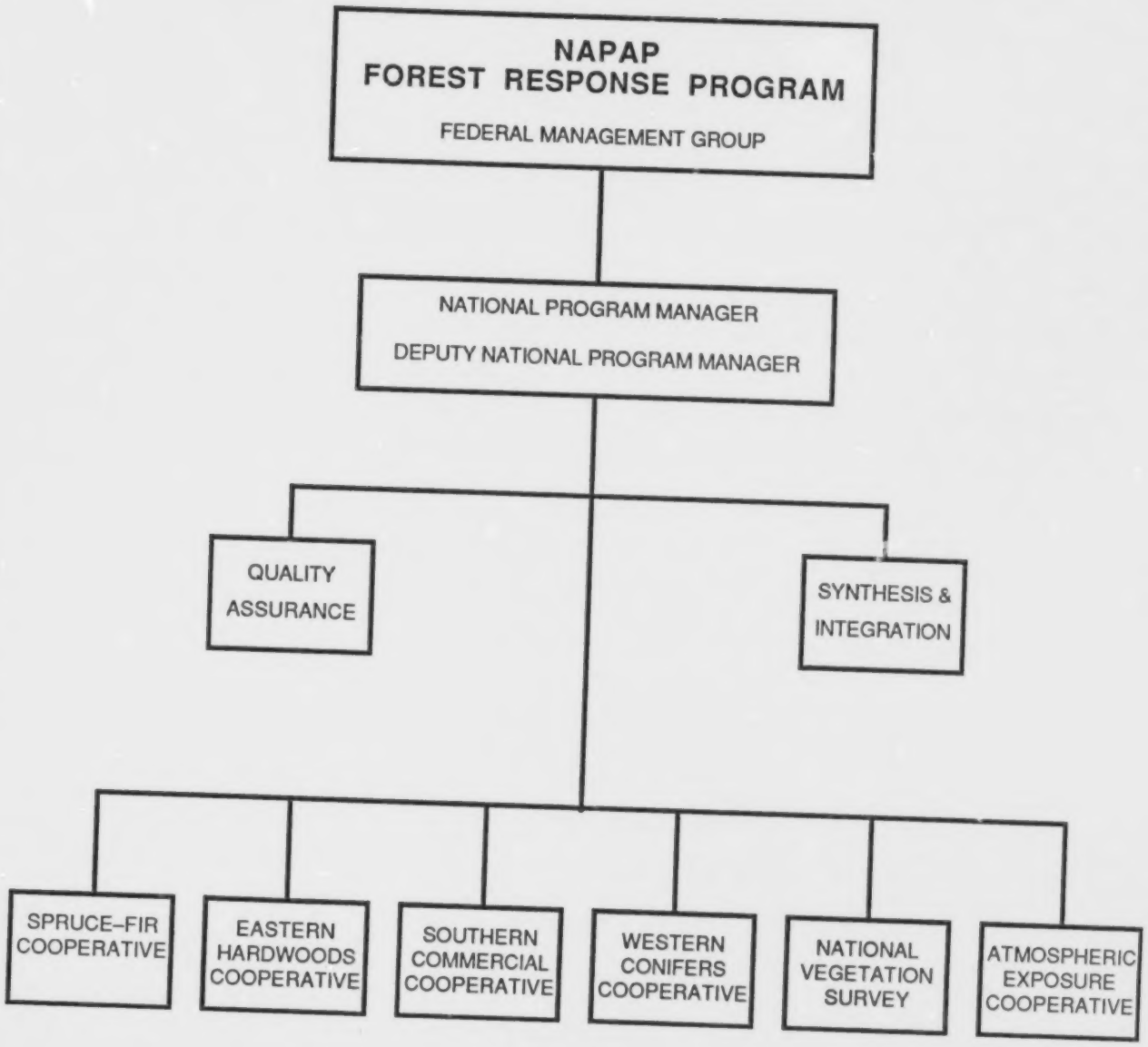

Fig 2. Organizational structure of the Forest Response Program. Names of key personnel are listed in section 10.

The Atmospheric Exposure Cooperative is responsible for: (1) characterizing deposition and air quality in U.S. forests on biologically relevant temporal and spatial scales, and (2) monitoring air quality at specific research sites.

The National Vegetation Survey has primary responsibility within the FRP for addressing Policy Question 1. The Survey's main activities include: (1) developing techniques for assessing forest condition relative to atmospheric pollutant exposure, and (2) applying these techniques to surveys of forest condition.

Also identified in Figure 2 are Quality Assurance and Synthesis and Integration groups. Their functions will be described later.

3.3 Research Strategy

3.3.1 Basic Approach

The Forest Response Program utilizes two major conceptual approaches to study the effect of atmospheric deposition on forests: (1) the epidemiological approach, and (2) the physiological/ecological approach. The epidemiological approach is characterized by broad surveys of forest condition and a search for patterns of condition that may be related to atmospheric deposition or other environmental patterns. This approach applies primarily to Policy Question 1. The physiological/ecological approach is characterized by more focused studies on the effects of particular environmental variables on the health of individual trees or stands and applies primarily to Policy Question 2. The general research strategy is for epidemiological studies to uncover spatial or temporal patterns which suggest particular hypotheses to be tested in a physiological or ecological study. Similarly, experimental research may identify a parameter related to pollutant exposure that can be used in a survey mode. Initial studies will concentrate on geographic areas of reported concern. If warranted, regional extrapolations will follow. The estimations of regional results will be achieved through models which combine physiological and ecological processes with forest dynamics (Policy Question 3).

The FRP research strategy is to address the Policy Questions concurrently. As stated above, research under one Policy Question may generate new hypotheses for testing under a different Policy Question. Also, a simultaneous effort is mandated by the time constraints imposed by policy clients facing regulatory decisions.

3.3.2 Scientific Questions

The three Policy Questions provide a framework for the FRP research program, but are too broadly phrased to serve as foci for specific research projects. To overcome this, the FRP translates the Policy Questions into more specific Scientific Questions that can be used to generate testable hypotheses. The Policy Questions and their related Scientific Questions are listed in Table 1. This list is based upon our current state of knowledge regarding the primary mechanisms by which atmospheric pollutants may affect forests, and is open to additions or changes as circumstances dictate.

Table 1. The three Policy Questions addressed by the FRP and the associated Scientific Questions. The order in which the Scientific Questions are listed does not represent the program's priorities.

Policy Question 1: Is there a significant problem of forest damage in North America which might be caused by acidic deposition, alone or in combination with other pollutants (e.g. SOx, NOx, metals, O_3, H_2O_2, or hydrocarbons)?

1.1 Are changes in forest condition greater than can be attributed to typical trends and levels of natural variability?

1.2 What spatial patterns exist in forest condition and how do these patterns relate to spatial patterns of pollutant exposure?

Policy Question 2: What is the causal relationship between acidic deposition, alone or in combination with other pollutants, and forest damage in North America?

2.1 What is the effect of sulfur and/or nitrogen pollutants on forests through the mechanisms of:

(1) Direct Toxicity to roots, mycorrhizae, or soil microbial populations by mobilized metals in acidified soil water;

(2) Nitrogen toxicity to mycorrhizae;

(3) Increased leaching of soil nutrients resulting in reduced nutrient availability.

2.2 What is the effect of sulfur and/or nitrogen pollutants, alone or in combination with oxidants, on forests by the mechanism of increased leaching of foliar nutrients?

2.3 What is the effect of sulfur and/or nitrogen pollutants, alone or in combination with oxidants, on forests by the mechanism of altering photosynthesis, respiration, and carbon allocation patterns (e.g., morphology) with possible induction of water and/or nutrient stress?

2.4 What is the effect of nitrogen compounds, possibly in combination with oxidants, on forests through the mechanism of delayed cold hardening or early break in dormancy resulting in increased winter damage?

2.5 What is the effect of sulfur and/or nitrogen pollutants, alone or in combination with oxidants, on forests through the mechanism of disrupting reproduction or regeneration?

2.6 What is the effect of sulfur and/or nitrogen pollutants, alone or in combination with oxidants, on forests through the mechanism of altered susceptibility to pests and pathogens?

Table 1 (continued)

Policy Question 3: What is the dose-response relationship between acidic deposition, alone or in combination with other pollutants, and forest damage in North America?
3.1 What is the dynamic response of forests to specified levels of acidic deposition, alone or in combination with other pollutants?

Because of regional differences in forest types, pollutant regimes and existing knowledge, the emphasis placed on each Scientific Question will vary between the Cooperatives. Physiological and ecological studies will be used to quickly eliminate as many proposed hypotheses as possible by analysis of both existing and newly collected data. This will allow targeting of research efforts and resources on hypotheses that cannot be readily eliminated. More intensive studies will then be planned to determine cause and effect relationships and to quantify tree response.

3.3.3 Synthesis and Integration

The FRP is a large and diverse research effort directed toward specific policy and regulatory questions. It is essential that projects within the FRP are well integrated and that project-level outputs support the development of the necessary program outputs. To meet these needs, the FRP developed the Synthesis and Integration (S&I) project. S&I is responsible for producing the major program-wide outputs and for ensuring that the program, as a whole, functions efficiently at the technical level. The eight members of the S&I Team are primarily modelers and statisticians with strong backgrounds in forestry and tree physiology.

Integration is achieved through a tracking system which follows the progress of each of the many individual research efforts within the research cooperatives. Proposed projects are evaluated for timeliness and relevance to program-wide outputs and for their role in addressing the Scientific Questions.

Synthesis is achieved through quantitative analyses and modeling of many different kinds of data produced by the Program. An approach based upon biological levels of organization distinguishes seedlings, whole mature trees, stands, and regions, and provides a structure to this diversity of data. A corresponding diversity of analytical and modeling methods provides for the simultaneous analysis of data at each level while attempting to understand the connections between levels. Extrapolation of responses to pollution, from seedlings to adult trees, from adult trees to stands, and from stands to regions are major tasks of synthesis. The ability to project the response to alternative deposition scenarios follows from an understanding of the dynamics of trees and forests affected by pollution.

The functional role of S&I within the FRP is illustrated in Fig. 3. The AEC and NVS conduct research both in support of the regional Cooperatives and in support of program-wide outputs. Some outputs of the regional Cooperatives will be solely end products, but most will be utilized by S&I in developing the FRP outputs. Outputs from non-FRP research programs are tracked by S&I and any applicable data is also utilized. Integration activities of S&I include facilitation of information exchange and collaborative efforts between Cooperatives and review of project proposals for relevance to program-wide outputs. They also include co-funding of projects whose outputs are of benefit to all of the Cooperatives and development of a central database for storage and retrieval of project outputs.

The five major FRP outputs that will be produced by S&I are listed in Table 2. They are directly related to the three Policy Questions. The emphasis on seedling response (output #3) reflects the large amount of FRP

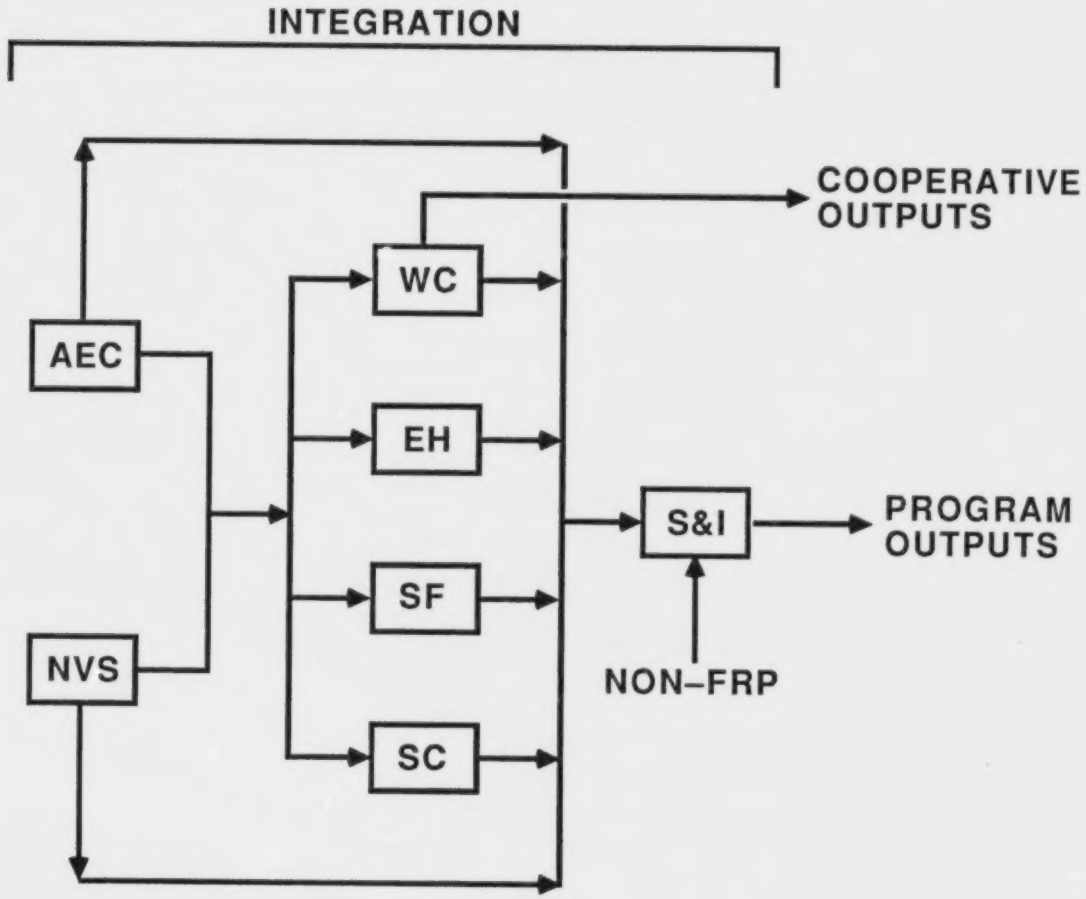

Fig 3. Research units and information transfer with in the Forest Response Program.

AEC = Atmospheric Exposure Cooperative
NVS = National Vegetation Survey
WC = Western Conifers Research Cooperative
EH = Eastern Hardwoods Research Cooperative
SF = Spruce–fir Research Cooperative
SC = Southern Commercial Forest Research Cooperative
S&I = Synthesis and Integration Project.

See text for explanation.

Table 2. Major Forest Response Program outputs (completion date)

1.	Evaluation of the extent and magnitude of recent changes in forest condition (12/88).
2.	Evaluation of the role of non-air pollution factors in growth reduction and visible decline (12/88).
3.	Quantitative estimates of seedling response to S, N, and associated pollutants at ambient conditions (12/87 and annually).
4.	Evaluation of the roles of S, N, and associated pollutants in forest effects (4/89, 4/91).
5.	Projection of responses under alternative deposition scenarios (12/91).

research which utilizes seedlings. S&I is devoting considerable effort to addressing the question of extrapolating from the response of seedlings to the response of mature trees and stands.

3.3.4 Quality Assurance

Integration within the FRP is greatly strengthened by an internal Quality Assurance (QA) Project with a current staff of four.

The goal of QA is to ensure that Forest Response Program data are of known and sufficient quality to meet their intended use for the synthesis and integration of research results, leading to the assessment of atmospheric deposition effects on forest ecosystems. The following objectives are designed to achieve this goal:

1. Provide guidance, reinforcement, and resources to the investigators for the implementation of QA activities;

2. Assure comparability of research and QA activities across sites and over time;

3. Examine, evaluate, and adjust research and QA activities to assure continued compliance with standard or approved protocols and procedures; and

4. Provide evidence of research data quality through qualitative and quantitative evaluations.

A QA Specialist has been assigned by the QA Project to each of the Cooperatives. The Specialists review all project proposals and work with the principal investigators to develop an acceptable QA Plan prior to funding. The Specialists then conduct periodic site audits and work with the investigators to resolve any QA problems.

These activities have proven to be extremely beneficial in terms of developing and maintaining the highest quality research by the Cooperatives. Salary and expenses of the QA Specialists are paid by the QA Project.

3.4 Documentation

Additional information on the FRP can be obtained from a number of program documents. Most important are:

-- National Research Plan for the Forest Response Program
-- Synthesis and Integration Project Research Plan
-- Quality Assurance Implementation Plan
-- Research Plans for each of the Cooperatives

These documents may be obtained from the appropriate Team Leaders or Cooperative Directors listed in Section 10.0.

4.0 Western Conifers Research Cooperative

4.1 Objective

The preceeding sections describe the organization and research strategy of the FRP. The objective of the WCRC is to provide information in support of the FRP effort to address the three Policy Questions in the western United States. Research is restricted to the effects of atmospheric deposition on coniferous forests in this region.

4.2 WCRC Research Strategy

The WCRC's research strategy is the same as that of the FRP (Section 3.3) -- to address the Policy Questions through research at the level of the Scientific Questions. The relative emphasis placed on the Scientific Questions by Western Cooperative differs from that of the other Cooperatives because of: (1) differences between the West and the East in physical and biological variables, pollutant regimes, and state of knowledge; and (2) the current absence of any research by either the AEC or the NVS in the West.

Most of the Cooperative's outputs will be utilized by S&I in developing program-wide outputs. The WCRC works closely with S&I to ensure that the Cooperative's research projects are integrated with the S&I effort. Because the problem being addressed is complex and has many unknowns, research emphasis will certainly change as new data is acquired. To deal with this situation, the WCRC employs a research strategy that is flexible yet remains properly focused because it has:

(1) clearly defined goals (addressing the Policy Questions);

(2) a research framework (the Scientific Questions); and

(3) continuous interaction with S&I. This includes review by S&I of all project proposals for relevance to major outputs and review each year of the WCRC research plan.

4.3 Interactions with Other Programs

The WCRC conducts only a small part of the total research in the West that is investigating the effects of atmospheric pollutants on forests. Some of the major programs are listed in Table 3. The outputs from these and other efforts will play an important role in the development of the FRP outputs.

To maximize interaction with these programs, the WCRC is proposing as part of its 1987 program a system to track outputs from non-FRP programs in the West. This system, described fully in Section 8.0, is central to implementing the Cooperative's philosophy of avoiding unnecessary redundancy where other programs will already be supplying needed information. The Cooperative will target its efforts on the most critical gaps in the information required by S&I.

Table 3. Partial List of Major Western U.S. Research Programs Relevant to the Study of the Effects of Atmospheric Deposition on Forests.

National Council of the Paper Industry for Air and Stream Improvement -- Provides substantial technical and financial support to the Forest Response Program.

California Air Resources Board -- Extensive air quality monitoring. Development of a major forest effects program.

Electric Power Research Institute -- Provides major support for emissions inventories, air chemistry and deposition monitoring, atmospheric modeling, and extensive effects research programs (e.g., ROPIS and IFS).

National Atmospheric Deposition Program -- Primary wet chemistry data base of U.S. with over 60 monitoring sites in the West.

U.S. Department of Energy (Idaho National Engineering Laboratory) -- Major new program to examine environmental effects of energy production in the intermountain West.

University of Arizona Tree Ring Lab -- Extensive dendrochronological records from throughout the West.

U.S.D.A. Forest Service -- Timber Management and Forest Inventory Analysis sections maintain and update major data bases on species composition and timber growth on plots throughout the West. Rocky Mountain Forest and Range Experiment Station developing major ecosystems effects program. Intermountain, Pacific Northwest, Northern, Southwestern, and Pacific Southwestern stations operate smaller programs using "air quality related values" funding for wilderness research and a combination of USFS and extramural funds for additional research.

National Park Service -- Operates Fine Particle Network and other air monitors throughout the West, plus several long-term watershed and forest effects monitoring sites.

U.S. EPA -- Extensive data base of emissions inventories, pollutant modeling, and air quality monitoring networks (e.g., SAROAD) operated independently and through Regional Office funding to state programs. Some effects research funded directly through Regions 8, 9, and 10, while "pass through" funding to state agencies supports additional small projects.

Various state agencies -- National Science Foundation, energy companies, and other institutions fund and conduct additional projects.

Collaboration with other programs is actively sought in cases of mutual benefit. Collaboration can range from modification of a research project to better complement other work to co-funding of projects. The Cooperative is developing collaborative efforts with CARB, NCASI, U.S.F.S, and E.P.A. Region 8.

4.4 1986 Research Program

4.4.1 Overview

Because the 1987 program builds on the 1986 effort, it is necessary to review the 1986 program. Some of the 1986 projects are multi-year and will be continued in 1987. Other projects funded from the 1986 budget did not start until 1987 because approval of the 1986 plan did not occur until late April 1986. Proposal solicitation and review then pushed most projects into the following year.

The 1986 research program emphasized two Scientific Questions (S.Q.s): S.Q. 1.2 and S.Q. 2.3 (Fig. 4). Work under S.Q. 1.2 was devoted entirely to characterization of deposition patterns. The main projects under S.Q. 2.3 sought to characterize the relative responses of seedlings of the major western conifers to simulated pollutant regimes (Table 4).

There are several reasons for this initial bi-modal allocation of resources. The limited state of knowledge on air quality and forest health in the West leads the Cooperative to conduct broader survey type studies in advance of more detailed mechanistic work. The seedling exposures are designed to give an initial indication of the relative sensitivity of the major western conifers to direct effects of acid precipitation and related gaseous pollutants. This screening approach has been utilized by all the Cooperatives and provides a base for subsequent studies of mechanisms of direct injury, soil-mediated processes, and responses of mature trees.

The exposure regimes used by the Cooperative in its seedling studies simulate realistic western ambient regimes, but development of the regimes is often hindered by lack of air quality data in the West. Rural, high elevation areas are particularly poorly characterized. Thus, the Cooperative devoted over onethird of its 1986 commitments to S.Q.1.2 and improvements in characterizing spatial patterns of atmospheric deposition.

Data on cloud chemistry from Mt. Rainier (Table 4, Project 3) is already being used in refining the acid mist regimes at Corvallis (Project 8).

The second factor influencing the 1986 allocations will also strongly influence the 1987 program. The National Vegetation Survey (NVS) has primary responsibility within the FRP for addressing Policy Question 1 (S.Q.s 1.1, 1.2). The Atmospheric Exposure Cooperative (AEC) addresses some aspects of S.Q.1.2 through the Mountain Cloud Chemistry Project and through its air quality monitoring at forest effects research sites. Neither the NVS nor the AEC currently provide support in the West. Although this situation may change (Section 5.3), the WCRC has primary responsibility in FY86 and FY87 for addressing S.Q.s 1.1 and 1.2 in the West and its resource allocations will reflect that fact.

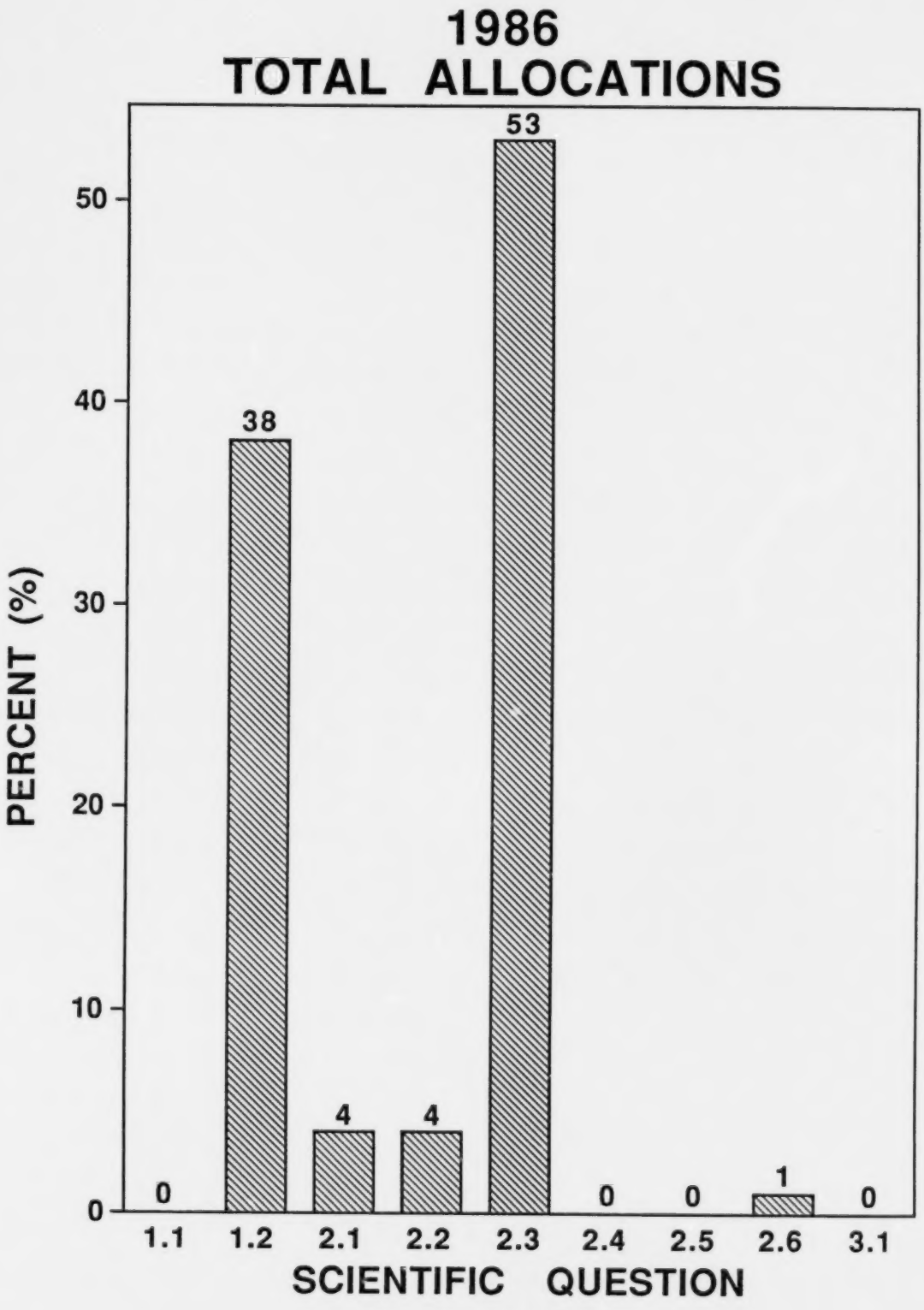

Fig 4. Allocation of expenditures for Western Cooperative 1986 research program.

Table 4. 1986 Western Cooperative research projects. Project descriptors may be found in Section 7.0.

Scientific Question	Project #	Project Description
1.2	1	Atmospheric science support for the WCRC.
	2	Recommendations for spatial characterization of gas and aerosol patterns using existing data.
	3	Monitoring of cloud chemistry, Mt. Rainier, Washington.
	4	Monitoring of cloud chemistry at Mt. Werner, Colorado.
	5	Monitoring of wet deposition at eight high elevation sites in the Rocky Mts.
	6	Development of an improved passive ozone monitor.
2.1 and 2.2	7	Foliar leaching and growth responses of western conifer seedlings exposed to acid mist and grown under different levels of nutrient availability.
2.3	8	Growth responses of western conifer seedlings to simulated ambient SO2 and acid mist/O3 regimes (EPA-Corvallis).
	9	Growth responses of western conifer seedlings to simulated ambient SO2 and acid mist/O3 regimes (USFS-Riverside).
2.6	10	Correlations between patterns of deposition and patterns of insect/pathogen occurrence; a pilot study.

The 1986 distribution of funds is also an artifact of program start-up. Everything can not be done the first year and priorities have to be set. Additional time is required to achieve an appropriate program balance (a balance likely to shift as the program evolves). One of the goals of the 1987 program is to achieve a more appropriate program balance.

4.4.2 1986 Projects

The 1986 research projects are listed in Table 4 and described in more detail in Section 7.0. Six projects address S.Q.1.2. Two of the projects evaluated the use of existing data to produce an improved characterization of deposition patterns. Compared to funding additional monitoring, this approach can be very cost-effective. However, some critical gaps in deposition data can only be filled with additional monitoring. Deposition to high elevation forests has been identified as one critical gap and the Cooperative in 1986 funded three monitoring efforts at high elevations. Finally, the Cooperative funded development of an improved passive ozone monitor to allow extensive surveys of general ozone concentrations as a means of targeting more accurate, but much more expensive, continuous monitoring with Dasibi or other powered monitors.

The two largest projects dealt with S.Q. 2.3. Seedlings of eight western conifers are being exposed in open-top chambers to simulated ambient regimes of SO_2, acid mist, and O_3. As stated earlier, the main purpose of these screening studies is to provide a base for future mechanistic work and to indicate for which species, if any, such work might be needed.

A single project looks at aspects of both S.Q. 2.1 and 2.2 by examining relationships between nutrient availability, acid mist induced foliar leaching, and growth effects on conifer seedlings. S.Q. 2.6 is also the focus of a single project: a pilot study to examine existing spatial information on insect/pathogen occurrences. These databases will then be evaluated for their usefulness in a possible correlation study with deposition patterns. S.Q. 2.4 and 2.5 were not addressed in FY86 because existing information did not justify examining those hypotheses in the West.

5.0 WCRC 1987 Research Program

5.1 Objective and Strategy

The objective of the 1987 research program is to implement new initiatives that will, when combined with the 1986 projects, provide an appropriate balance for the program in terms of effort devoted to each Scientific Question. As discussed earlier, an appropriate balance for the WCRC emphasizes S.Q. 1.1 and 1.2. The Cooperative currently has insufficient information to justify emphasizing any of the mechanistic Questions 2.1-2.6.

To achieve this balance, the 1987 program's new initiatives heavily emphasize S.Q.s 1.1. and 1.2 (Figure 5). New initiatives represent 80% of the 1987 budget, so that when combined with the 1986 projects proposed for continuation (Figure 6), the total program (Figure 7) emphasizes Policy Question 1 over Policy Question 2 by two to one. This is an appropriate balance for the Cooperative at this time.

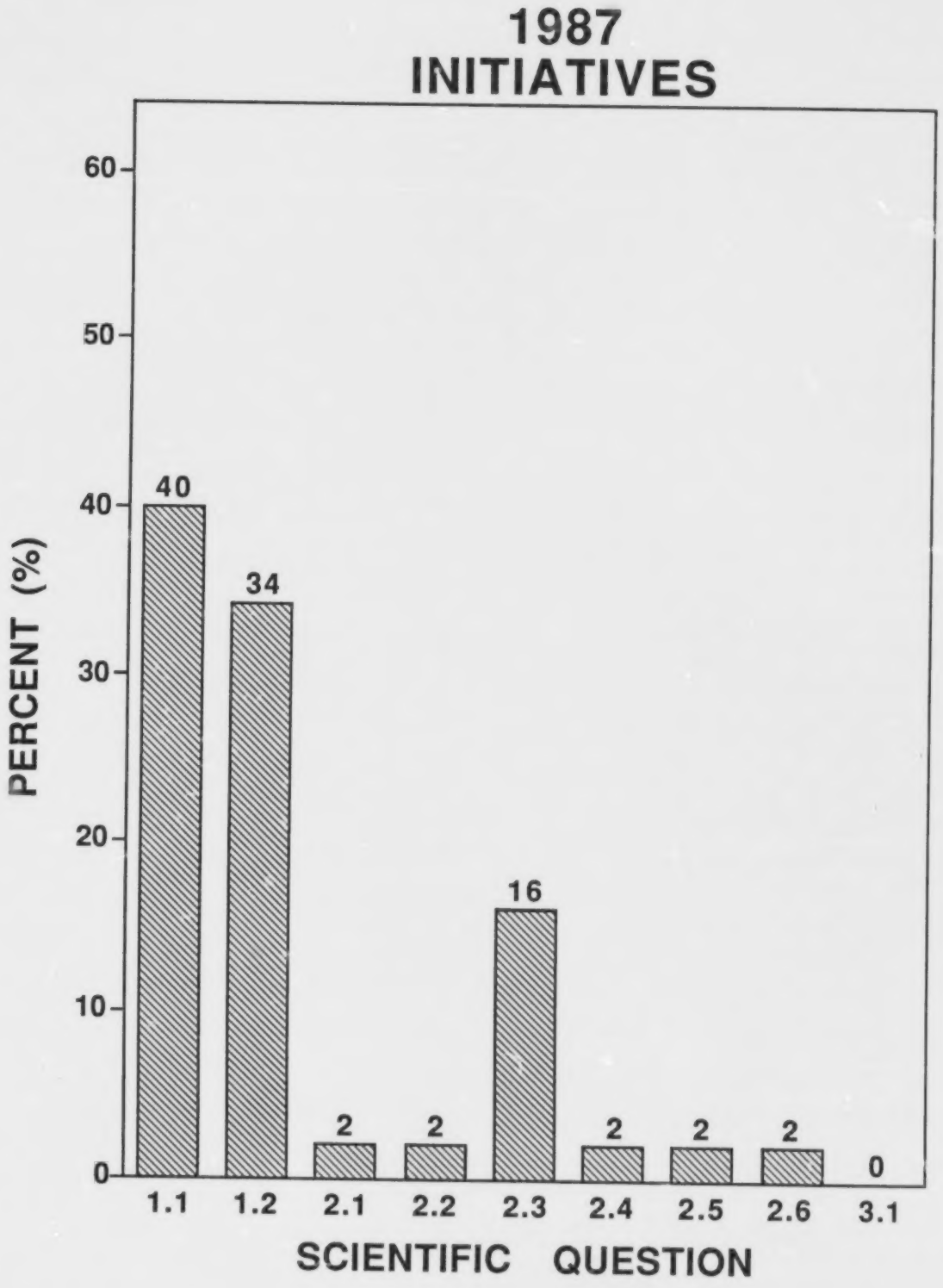

Fig 5. Allocation of Western Cooperative expenditures for 1987 new initiatives.

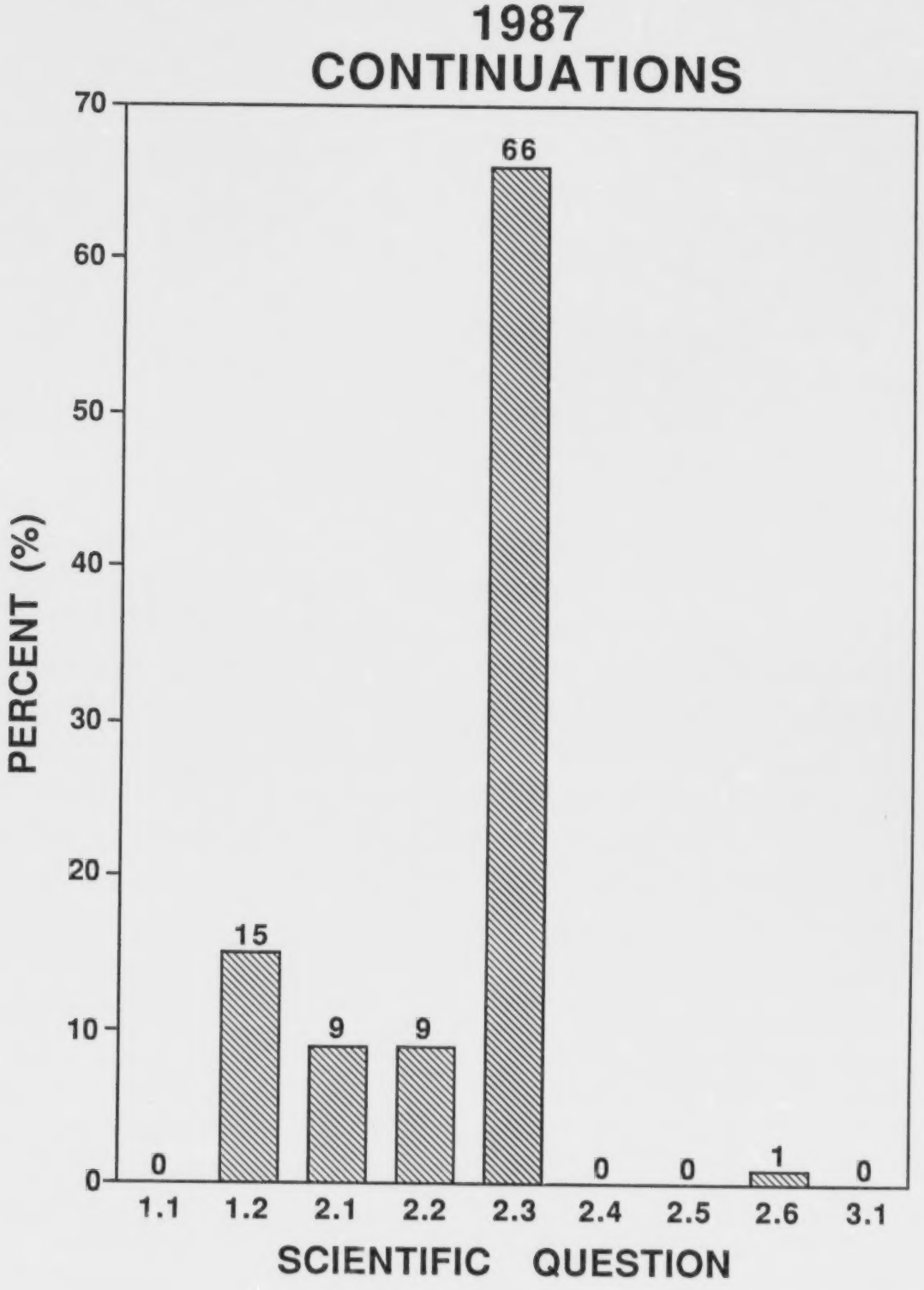

Fig 6. Allocation of proposed expenditures for continuation of Western Cooperative 1986 projects in 1987.

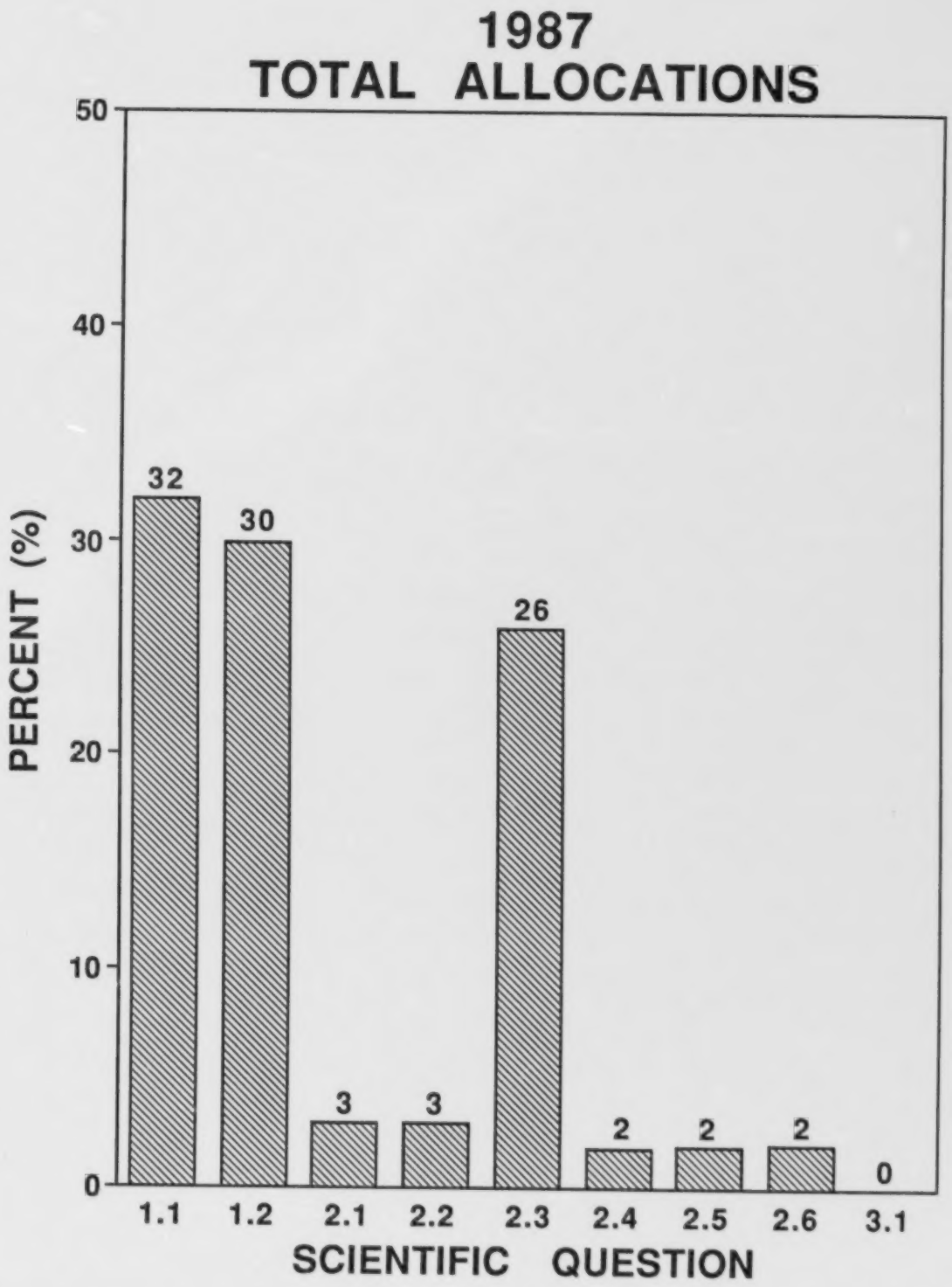

Fig 7. Allocation of total research expenditures for the proposed 1987 Western Cooperative research program.

The balance may change in future years as the Cooperative gains additional information. The broad investigations under Policy Question 1 may lead to new hypotheses or provide evidence that one of the mechanisms under S.Q. 2.1-2.6 is important and merits greater consideration. The screening studies under S.Q. 2.3 may provide similar information. Also, a small effort will be directed toward every Scientific Question, mainly in acquiring references from the literature and tracking relevant outputs from other research programs. The results of these efforts may also lead to a shift in emphasis.

Scientific Question 3.1 will be addressed by S&I and will not receive direct attention from the WCRC. The Cooperative's regular interaction with S&I will ensure that the Cooperative's outputs will support S&I's evaluation of S.Q. 3.1.

5.2 1987 research projects

The individual research projects included in the 1987 program are listed in Table 5 and described in more detail in Section 8.0. Eighteen projects will be funded 1987: five continuations of 1986 projects and thirteen new initiatives.

5.2.1 Continuations

The rationale for initiating these five projects was given in Section 4.0. All of them require further time and funding in order to meet their objectives.

The Cooperative's support in 1986 for the Rocky Mountain Deposition Monitoring Project (RMDMP) assisted the establishment of eight NADP monitoring sites and contributed to their operation through December 1986. Because of variability in precipitation chemistry and volume over time, RMDMP will operate for at least three years.

The three 1986 projects involving experimental manipulations of seedlings will be continued in 1987. Part of the first year of the foliar leaching experiment (Project 7) will be used in technique development and acclimation of seedlings to a hydroponic growing environment. The project will require a total of two years to complete enough replicates of its twelve week experiments to meet the statistical requirements for a sufficiently powerful test of deposition effects.

For the open-top chamber exposure studies, the experimental designs call for completion of the research in 1988. Available facilities limit the number of exposures that can be run concurrently. In order to complete two replicates each of the SO_2, acid mist, and ozone experiments, a continuation of the project is required.

Finally, the insect/pathogen pilot study is scheduled for completion in April 1987.

Table 5. 1987 WCRC research projects. Project descriptions may be found in Section 8.0.

Scientific Question	Project #	Project Description
All	11	Develop and maintain a computer data-base of current and proposed atmospheric deposition/forest effects research in the West.
All	12	Develop and maintain a computer literature database of appropriate references on atmospheric deposition and forest effects in the West.
1.1	13	Analysis of trends and natural variability in growth of selected western forests using existing forest plot remeasurement and dendrochronological databases.
	14	Development of a comprehensive plan for forest effects research in California.
	15	Evaluation and monitoring of the effects of atmospheric deposition on forest conditions in California.
1.2	5	Continuation of monitoring wet deposition at 8 high elevation sites in the Rocky Mts.
	16	Development and application of remote sensing techniques for the evaluation of forest condition in the western U.S.
	17	Monitoring the frequency of exposure of selected western forests to clouds and fog.
	18	Evaluation of forest response to ambient pollution levels in northwestern Washington/southwestern British Columbia.
	19	Air quality monitoring support for Project 18.
2.1	7	Continuation of foliar leaching/nutrient availability study.
2.2	7	Continuation of foliar leaching/nutrient availability study.
2.3	8	Continuation of seedling exposure studies, EPA-Corvallis.

Table 5 (continued)

Scientific Question	Project #	Project Description
	9	Continuation of seedling exposure studies, USFS-Riverside.
	20	Assessment of a branch enclosure technique for detection of air pollutant effects on foliage of large conifers.
	21	Development and evaluation of methodology for air pollutant exposure of mature forest trees.
	22	Determination of spectral characteristics of conifer species exposed to simulated pollutant regimes.
2.6	10	Continuation of pilot study on insect/pathogen interactions with atmospheric pollutants.
2.1 - 2.6	23	Open solicitation of proposals to address any of Scientific Questions 2.1 - 2.6 as appropriate to the western U.S.

5.2.2 New Initiatives

Technical details of the thirteen new initiatives (Table 5) are described in Section 8.0. Their integration in the WCRC research program is described below.

A thorough knowledge of past, current, and even anticipated research by other programs in critical to the success of the Cooperative. The Cooperative will track this information by maintaining two computer databases (Projects 11 and 12). One database will contain relevant literature citations for air pollution effects on western forests. A major use of this database will be to support development of "white papers" on each of S.Q. 2.1-2.6 for the West. These in turn will be used to evaluate the need for initiating research on these S.Q.s in 1988.

The second database will track current and planned research in the West by programs outside the FRP. This system will be used in program planning to avoid unnecessary duplication and to indicate opportunities for collaboration with other programs.

5.2.2.1 New Inititatives For S.Q. 1.1

S.Q. 1.1 -- "Are changes in forest condition greater than can be attributed to typical trends and levels of natural variability?" -- is a central question for the WCRC. It is also the reason for one of the major S&I outputs, an evaluation of the extent and magnitude of recent changes in forest condition (Table 2).

This Scientific Question was not addressed by the Cooperative in 1986, so it needs to be emphasized in 1987. To answer this question requires information on spatial and temporal variability in forest growth. Since such information is very expensive to acquire, the Cooperative held a workshop in early October to explore the possibility of using existing databases to look at S.Q. 1.1. The conclusion was that there are a number of existing dendrochronological and forest plot remeasurement databases that may be very useful. These databases are held by the U.S. Forest Service Forest Inventory Analysis and Timber Management groups, several universities, and private industry. Project 13 was developed to make use of these often unique databases.

Projects 14 and 15 are placed under S.Q. 1.1, although they will eventually encompass all of the Scientific Questions. Part of the WCRC's research strategy is to maximize collaboration with other programs in cases of mutual benefit. The California Air Resources Board is currently developing an air pollution/forest effects program whose objectives overlap those of the Cooperative. The Cooperative will participate in the development of a forest effects research plan for California (Project 14) and will contribute to the research effort when the plan is implemented (Project 15).

5.2.2.2 New initiatives for S.Q. 1.2

The 1986 research program addressed S.Q. 1.2 only in terms of characterizing deposition patterns. The 1987 projects provide a better balance by also looking at patterns of condition.

Methods for the regional characterization of forest condition are lacking, but are obviously needed by the Cooperative. The National Vegetation Survey is currently testing remote sensing techniques for use in evaluating extent and degree of spruce-fir decline. The WCRC will support development of similar techniques geared to the unique forest conditions of the West (Project 16).

A study of the relationship between deposition and forest condition is already planned for California (Project 15). The Puget Sound region of Washington and British Columbia has a combination of elevated pollution levels and extensive forest resources which make it a logical next area for such a study (Project 18). Other areas of the West will be considered for this type of study in future years. Air quality monitoring sites will be established and operated as part of this study (Project 19).

The 1987 Plan includes a new initiative related solely to deposition patterns (Project 17). The Cooperative is already funding studies of cloud chemistry (Projects 3 and 4). There was some difficulty in siting the studies because of the lack of information on the frequency with which various forests are exposed to clouds or fog. Additional information on cloud frequency is critical to an accurate assessment of the potential effects of cloud deposition on forests, and Project 17 will characterize cloud frequency for a selected region.

5.2.2.3 New Initiatives for Scientific Questions under Policy Question 2

All of the Scientific Questions under P.Q. 2 will be addressed by the literature and current research databases (Projects 11 and 12). The outputs from these projects will be used to determine future initiatives for these questions.

Three new initiatives are directed at S.Q. 2.3. Projects 20 and 21 both involve development of methodologies for working on one of the Forest Response Program's major concerns. Much of the FRP's experimental manipulations involve seedlings, yet little is known about the comparability of seedling response to that of mature trees. Project 20 will develop methods for exposing (or protecting) attached branches of mature trees to gaseous pollutants while minimizing alteration of the branch environment. Branch responses will be compared to those of seedlings and grafts of mature tissue exposed to the same regimes.

Project 21 takes the next step and develops methods for exposing whole mature trees. This project is an initiative of the Southern Commercial Cooperative. Since the results are of importance to the whole FRP, the WCRC will support this effort.

Project 22 examines changes in the spectral characteristics of conifer seedlings exposed to controlled pollutant regimes. The early results of this project will be used to evaluate proposals for expanded research (Project 16).

The final new initiative, Project 23, is an open solicitation of proposals to address any of Scientific Questions 2.1-2.6. The Cooperative has already received comments from many western scientists on its draft 1987 Plan. Project 23 is an additional means of soliciting input on which mechanisms of pollutant action are felt to be important in the West. Proposals will be evaluated for

relevance to the program and evidence of the importance of the proposed hypotheses in the West. Proposals demonstrating that an effort toward a particular Scientific Question is justified will either be funded in 1987 or will be used in planning research for subsequent years.

5.3 Interactions with NVS and AEC

The WCRC will work to increase its interactions with the NVS and AEC in 1987. The NVS will review all proposals received by the WCRC for gradient studies or surveys of forest condition. The NVS will also arrange and participate in meetings between WCRC investigators and scientists heading related studies for other Cooperatives.

The AEC is currently developing standard protocols for atmospheric monitoring in support of FRP effects research. The WCRC will follow these protocols when possible and seek AEC guidance for all monitoring activities. Direct support for monitoring at intensive research sites will be sought from the AEC for 1988. The atmospheric scientist to be based at Corvallis (Project 1) will act as a liaison between the WCRC and the AEC.

6.0 WCRC Management

6.1 Administration

The WCRC is a project of the U.S. Environmental Protection Agency, Environmental Research Laboratory -- Corvallis (ERL-C). It is administered within the Air Branch (Figure 8). Through a specific agreement between the U.S. EPA and the U.S. Forest Service, the WCRC functions as part of the Forest Response Program (FRP). The WCRC's funds are disbursed through the U.S. EPA and all Cooperative projects must meet EPA and ERL-C requirements for funding mechanisms.

6.2 Staff

The Cooperative has two full-time staff members: the Cooperative Manager, Richard Olson, and a technical support staffer, Danny Rambo. In addition, a secretary is assigned half time to the Cooperative.

Specific responsibilities of the Cooperative Manager, as outlined in the FRP National Plan, include:

(1) develop a research plan annually to guide research consistent with objectives specified by National Program Management;

(2) prepare Request for Proposals;

(3) receive proposals and review proposals according to procedures established by the Federal Management Group (FMG), select the best proposals, and prepare funding recommendations for submission to National Management;

(4) provide technical direction to inhouse staff working within the Cooperative;

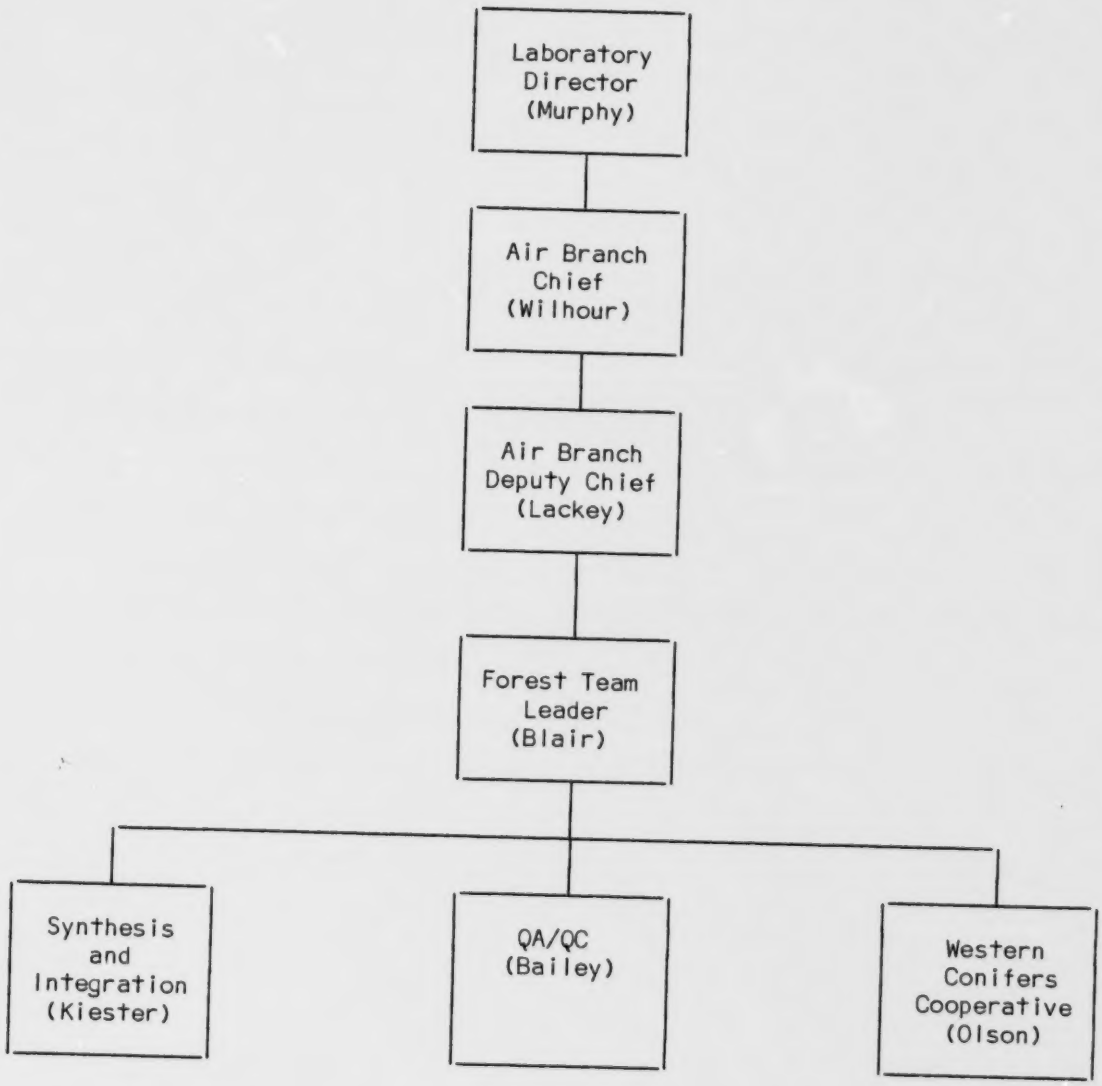

Figure 8. Administration of the Forest Effects Team, Environmental Research Laboratory-Corvallis.

(5) conduct annual technical reviews of individual projects;

(6) integrate research results for the Cooperative to meet major objectives and outputs specified by National Management;

(7) develop effective database management with formats in common with other research Cooperatives (where practicable) and the national database management; and

(8) develop and implement procedures consistent with QA/QC requirements specified by the Federal Management Group and National Management.

Mr. Rambo's time is divided evenly between development of the research database (Project 11), development of the literature database (Project 12), completion of the insect/pathogen pilot study (Project 10), and general technical support for the Cooperative Manager. Resumes for Mr. Olson and Mr. Rambo are given in Appendix A.

6.3 Plan and Project Approval

The FRP has designed a rigorous review process to ensure that all research conducted by the Cooperatives meets the policy needs of the program and that all projects are of the highest technical quality. As part of the U.S. EPA, the WCRC must also meet all EPA requirements for funding research.

The major tasks involved in the funding of research by the WCRC are listed in order in Table 6. In order to meet the goals stated above, the Research Plan and each research project are reviewed by National Management, Synthesis and Integration and a technical peer review group. Research projects must also have an approved QA/QC plan.

Although the Cooperative Manager is responsible for developing the annual Research Plan, the process involves a large group of scientists. The 1987 WCRC Research Plan is based on output from several workshops and numerous individual comments received in response to the circulation of an early draft Plan. This input from western scientists and resource managers has helped to shape the current Plan.

6.4 Database Management

Projects within the WCRC will be producing a large amount of very diverse data over an extended period of time. The Cooperative is paying for the data because the data is needed for the evaluations to be conducted by the WCRC and by S&I. To be useful for this purpose, the data must be stored securely and in an easily accessible form.

The WCRC is currently developing in conjunction with S&I a professionally operated central database. All data produced by WCRC projects will be entered into the database on a regular basis under the direction of the WCRC QA Specialist. The goal is to have a secure, quality assured database which will maximize the quality of the data for its intended use. The WCRC recognizes the perogative of its investigators to publish their results. Submission of data to the WCRC database will in no way infringe upon that right.

Table 6. Sequence for approval and funding of THE WCRC Research Plan and associated research projects. FMG = Federal Management Group, NPM = National Program Management.

RESEARCH PLAN
° Cooperative Research Plan developed by Cooperative Manager.
° Review of plan and concurrence by FMG, NPM, and S&I.
° Technical peer review of Plan.
° Revision of Plan to address reviewers' recommendations.
° Final Plan approval by FMG, NPM, and S&I.
RESEARCH PROJECTS
° Proposals solicited based on approved Research Plan.
° Peer review and selection of proposals for funding.
° Selected proposals revised to address reviewers' recommendations.
° Approval of proposal by Cooperative Manager and QA Specialist.
° Final approval by FMG and S&I.
° Funding package sent to EPA Grants Adminstration Division.
° Release of funds to recipient organization by EPA.

7.0 Descriptions of 1986 Western Cooperative Research Projects

This section contains a 1-2 page description of each of the ten 1986 projects conducted by the Western Cooperative. They are presented in order by project number.

Project Number: 1

Project Title: Atmospheric science support for the WCRC.

Period of Performance: 1987/continuing

Principal Investigator: Dr. James H. Gibson
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado 80523

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $60,000

State/Region of Research: U.S. with emphasis on West

Scientific Question Addressed: S.Q. 1.2

Objective: To increase the capability of the WCRC to address questions involving atmospheric science and to increase the Cooperative's ability to interact with ongoing atmospheric modeling and monitoring efforts within and outside of the FRP.

Project Description:

An understanding of patterns of atmospheric deposition is essential to the success of the WCRC. To achieve this understanding, the Cooperative participates in projects ranging from monitoring of pollutant concentrations at biological effects research sites to evaluating the utility of transport and deposition models. The specialized nature of many of these projects requires the WCRC to obtain additional expertise.

As part of a larger agreement between EPA-Corvallis and Colorado State University, the WCRC will bring an atmospheric scientist to Corvallis for a period of at least one year. The scientist will support the WCRC by:

-- Constructing a virtual database of atmospheric deposition and concentration data for the West. A virtual database does not contain the actual data, but contains information on the location, format, access, and quality of appropriate databases.

-- Planning and overseeing WCRC projects for characterizing patterns of deposition in selected regions of the West.

-- Acting as the WCRC liaison to the AEC and to monitoring and modeling projects outside of the FRP.

-- Overseeing monitoring at WCRC research sites.

(Project 1, continued)

In addition, the scientist will work with the S&I Team on a national level to evaluate the utility of existing transport and deposition models, to inventory and evaluate deposition databases, and to produce evaluations of the effect of atmospheric pollutants on forests in the U.S. The scientist will also interact closely with groups at Corvallis which are investigating the effects of acid deposition on aquatic systems and watersheds.

Progress (01/01/87): A schedule and procedure for implementing this project are being negotiated with CSU.

Project Number: 2

Project Title: Spatial characterization of gas and aerosol concentrations in the West: options for acquiring and synthesizing existing data.

Period of Performance: July-August 1986

Principal Investigators:

Dr. David Dietrich
Air Resource Specialists, Inc.
634 S. Mason Street
Fort Collins, Colorado 80524

Dr. John Hubbe
Battelle Pacific NW Labs
P.O. Box 999
Richland, Washington 99352

Dr. Timothy Larson
FX10, Wilcox 265
Department of Civil Engineering
University of Washington
Seattle, Washington 98195

Dr. Douglas A. Latimer
Systems Applications, Inc.
101 Lucas Valley Road
San Rafael, California 94903

Dr. Allen S. Lefohn
ASL and Associates
111 N. Last Chance Gulch
Helena, Montana 59601

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: $5000

State/Region of Research: West-wide

Scientific Questions Addressed: S.Q. 1.2

Objectives:

1) Determine how the Western Cooperative can best and most cost-efficiently acquire and synthesize current information on spatial patterns of forest exposure to atmospheric pollutants (SO_4 and NO_3 aerosols, O_3, SO_2, NO_x, metals, H_2O_2, etc.).

2) List primary sources of monitoring data and model outputs which should be assembled to develop a current picture of air pollution in western forests.

3) List published, unpublished and ongoing efforts to summarize and/or synthesize air pollution data in the West.

(Project 2, continued)

4) Provide recommendations for work that would significantly improve existing characterizations of western air pollution.

Project Description:

As part of its plan to assess current and potential effects of atmospheric deposition on western forests, the Western Cooperative is evaluating which western forests receive the highest exposure to atmospheric pollutants. Work on patterns of wet deposition is already planned. Planning for characterization of forest exposure to gases and aerosols is underway. As part of this process, contracts have been established with a diverse group of air quality experts to develop reports meeting the objectives listed above.

Deliverables: Final reports, August 1986.

Progress:

All reports completed and received at Corvallis. After a review of these reports, the Western Cooperative decided not to fund further extramural analysis of existing data on gas and particulate concentrations in 1987. Ongoing or planned efforts by other programs in monitoring and transport modeling will add significantly to the existing database over the next 1-2 years. It is appropriate to wait and evaluate the results of these studies before planning additional work. This evaluation will be one of the primary duties of the atmospheric scientist brought to Corvallis as part of Project 1.

Project Number: 3

Project Title: Characterization of fall cloud chemistry at a high elevation site, Mt. Rainier, Washington.

Period of Performance: September 1986-June 1987

Principal Investigators: Dr. Timothy Larson
Department of Engineering
University of Washington
Seattle, Washington 98195

Dr. Robert Edmonds
College of Forest Resources
University of Washington
Seattle, Washington 98195

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: $25,000

State/Region of Research: Northwestern Washington

Scientific Questions Addressed: S.Q. 1.2

Objectives: 1) To characterize the chemical composition of mountain cloud-water during the fall of 1986 at a high elevation site in Mt. Rainier National Park.

2) To determine whether cloud chemistry varies significantly between cloud events at Rainier.

3) To compare the chemistry of clouds sampled at Rainier with published and unpublished data on cloud chemistry at other sites in western Washington and throughout the United States.

Project Description:

Cloud/fog samples will be collected 2-4 times per month during October-November 1986 at an approximately 1830 m elevation site on the western slope of Mt. Rainier, Washington. This site is potentially influenced by emissions from the Seattle and Portland urban areas. Vegetation at this site is dominated by subalpine fir (Abies lasiocarpa) and mountain hemlock (Tsuga mertensiana).

The cloud collector will be located in a clearing which meets the requirements of the NADP/NTN network for siting of wet deposition collectors. Sampling protocols are designed to ensure comparability of data with the Mountain Cloud Chemistry Program of the Forest Response Program.

Supporting information collected at this site by the National Park Service includes rain amount, minimum and maximum daily temperatures, hourly average wind speed and direction, weekly average rainwater chemistry, photographic

records of visual range taken three times daily (frequency of daytime cloud and fog events), fine particle sulfate aerosol concentrations, and observer weather reports once daily at 0730. (Based on these reports, this site is believed to be one of the "foggiest" on the mountain.)

For this study, cloud events will be characterized with regard to liquid water content, pH, and Na, K, Ca, Mg, NH4, NO3, SO4 and Cl concentrations. Cloud chemistry will be compared between different cloud events on Rainier, between Rainier and low elevation sites in northwestern Washington and between northwest Washington and other cloud monitoring sites in the United States.

Deliverables: 1) Interim report: January 1987. Will include pH and ionic composition of cloud events sampled to date.

2) Final report: June 1987. All cloud chemistry collected during the study. Synthesis of supplemental meteorological data. Comparison of Rainier results with results of studies in other locations in Washington and the United States.

Progress (01/01/87): Cloud sampling continuing. Cloud water samples collected to date have pHs ranging from 3.6-4.2.

Project Number: 4

Project Title: Characterization of cloud chemistry and frequency of canopy exposure to clouds at Mt. Werner, Colorado.

Period of Performance: February 1987-January 1987

Principal Investigator: Dr. David F. Miller
Dr. Randolph D. Borys
Desert Research Institute
University of Nevada System
Reno, Nevada 89506

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $90,000

State/Region of Research: Colorado

Scientific Question Addressed: S.Q. 1.2

Objective: Analyze cloud chemistry and the frequency of exposure of the forest canopy to clouds at a high elevation forested site in the central Rocky Mountains during the growing season.

Project Description:

Cloud deposition is known to be an important source of water and chemicals for certain high elevation forests in the eastern U.S.. This input has been hypothesized as playing a role in the possible decline of eastern spruce-fir forests. A threat to western high elevation forests is often inferred, yet meteorology, climate, pollutant loads, and many other factors are considerably different in the West than in the East. Very few measurements of cloud chemistry and frequency have been made in the West, particularly at high elevations.

Efforts to examine cloud chemistry are currently proposed at high elevations in the Cascades and Sierras. To expand this effort to another region of the West, the Western Cooperative intends to fund cloud monitoring at the Storm Peak Laboratory on the summit of Mt. Werner, Colorado (3220m). In addition to measuring cloud chemistry and frequency during the growing season, the study will:

- Measure precipitation amount and frequency at the mountain field site.
- Determine the chemical composition of rainwater during periods when precipitating clouds impact the mountains.
- Determine the average concentration of acidic gases and airborne particulates during periods when clear air conditions prevail at these sites.

- Measure the meteorological conditions associated with the study period.

- Develop time-series presentations of the cloud-water composition based on measured solute concentrations and cloud liquid water content.

These values will be compared with rainwater composition and volume during periods of precipitating clouds.

- Evaluate the representativeness and significance of the data and its relation to other studies.

Chemical analyses of cloud and rain water will include pH, Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, and SO_4^{2-}. The cloud collector to be used allows direct measurement of cloud liquid water content. The data derived from this work will be comparable to that produced by the Mountain Cloud Chemistry Program (MCCP) of the Forest Response Program.

Deliverables: Final report, January 1988.

Project Number: 5

Project Title: Rocky Mountain Deposition Monitoring Project

Period of Performance: July 1986-indefinite

Principal Investigator: Mr. Larry Svoboda
U.S. Environmental Protection Agency
Region 8
999 18th Street
Denver, Colorado 80202

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $8,000

State/Region of Research: Rocky Mountains, Colorado and Wyoming

Scientific Question Addressed: S.Q. 1.2

Objective: To characterize wet deposition at eight high elevation sites in the Rockies and to evaluate the effect of elevation on rates of wet deposition in complex terrain.

Project Description:

The Rocky Mountain Deposition Monitoring Project (RMDMP) is a collaborative effort between the Western Conifers Research Cooperative, the U.S. Environmental Protection Agency--Region 8, the U.S. Forest Service--Region II, the U.S. Forest Service Rocky Mountain Forest Experiment Station, the Wyoming Water Research Center, and the Institute of Arctic and Alpine Research, University of Colorado.

The RMDMP will establish and operate paired Aerochem wet deposition collectors at four high elevation locations in the Rocky Mountains of Colorado and Wyoming. The sites will be operated as part of the National Acid Deposition Program monitoring network. The two collectors at each location will occupy the same airshed, but will be separated by about 2000 feet elevation. The precipitation chemistry and volume data collected by the RMDMP will be used to:

1) characterize wet deposition at eight high elevation sites in the Rocky Mountains, and

2) evaluate the effect of elevation on wet deposition rates in complex terrain.

All of the four study areas are believed to be exposed to different pollutant regimes from different source types, namely:

Area 1 -- Snowy Range, Wyoming: no predominant sources

(Project 5, continued)

Area 2 -- Buffalo Pass, Colorado: possible sulfate deposition from coal fired power plants

Area 3 -- Niwot Ridge, Colorado: possible nitrate deposition from urban sources

Area 4 -- San Juan Mountains, Colorado: possible sulfate deposition from copper smelters including future influence of Mexican smelters.

Deliverables: Annual reports, December of each year.

Progress (01/01/87): All eight sites are established and operating.

Project Number: 6

Project Title: Development and testing of an improved passive ozone monitor for outdoor monitoring.

Period of Performance: January 1987-December 1987

Principal Investigator: Dr. Dagmar Cronn
Laboratory for Atmospheric Research
Washington State University
Pullman, Washington 99164

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $55,000

State/Region of Research: Not regional in nature

Scientific Question Addressed: S.Q. 1.2

Objective: To develop an improved passive ozone monitor for use in remote rural areas.

Project Description:

Ozone is one of the most widespread atmospheric pollutants in the western United States. An evaluation of the effects of sulfur and nitrogen has to consider interactions with ozone. However, the density of ozone monitors in the West is low, particularly in rural and high elevation areas where most western forests are located. Areas where ozone concentrations have been assumed to be low may, as is the case for forested areas outside of Seattle, be found to have relatively high concentrations when monitoring is actually conducted.

Broad surveys of ambient ozone concentrations are not feasible with continuous instrumental ozone analyzers because of the expense of purchasing and operating the monitors. Inexpensive passive ozone monitors would be more appropriate for surveys. Although they are of limited use in effects studies because they do not give information on peak concentrations and other aspects of the exposure profile, they would be useful for screening and comparing a large number of sites. This information could then be used to target intensive monitoring.

The monitor to be developed in this study will utilize a chemiluminescent reaction between ozone, gallic acid and rhodamine B. The reaction will occur on a disk which abuts another disk of unexposed photographic film. The light from the reaction is recorded on the film and the degree of film exposure gives an integrated measure of ozone concentration for the sample period. The disks will be housed in a small box whose entrance consists of a series of baffles that admit air while excluding light.

(Project 6, continued)

Development of the monitor will involve extensive testing to determine response curves and evaluate effects of potential interfering pollutants and meteorological variables. The study will conclude with a series of field tests.

Deliverables: Prototype monitors for field testing, July 1987. Final report, December 1987.

Project Number: 7

Project Title: The effect of acid precipitation on seedling growth as a function of foliar leaching, foliar nitrate uptake, and cation availability.

Period of Performance: August 1986-October 1988

Principal Investigator: Dr. David Tingey
U.S. Environmental Protection Agency
Environmental Research Laboratory-Corvallis
200 S.W. 35th Street
Corvallis, Oregon 97333

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $50,000

State/Region of Research: Western U.S. with regard to species being manipulated.

Scientific Question Addressed: S.Q. 2.1, 2.2

Objective: Evaluate the roles of foliar cation leaching and cation availability to the roots in the responses of two coniferous species of the western United States to acidified mist.

Project Description:

Decreased forest productivity and tree-die back, in some cases tree death, is occurring in some areas of eastern North America and central Europe which are exposed to atmospheric pollution and associated acid rain. Symptoms in some cases include those indicating deficiencies in nutrient cations such as magnesium. Three factors associated with acid rain which might contribute to cation deficiencies in the foliage are 1) acid rain enhanced leaching of cations from the foliage, 2) a high requirement for cations in the foliage due to uptake of nitrate from the precipitation, and 3) reduced availability of cations in the soil due to acid rain enhanced leaching from the soil. The relative importance of these three variables is difficult to assess in the field but an understanding of their relationship is critical to predicting the effects of different acid rain regimes on vegetation.

A greenhouse study has been designed to evaluate the interaction of foliar cation leaching and root uptake of cations in the responses of two coniferous species of the western United States to simulated acid mist. The basic hypothesis is that tree seedlings can tolerate acid precipitation enhanced leaching of cations only if they can compensate for these losses by increased uptake of cations by the roots.

Containerized seedlings of Douglas fir and Engelmann spruce will be obtained from commercial sources and cultured in a greenhouse at the Environmental Research Laboratory-Corvallis. At approximately six months of age,

individual seedlings will be transferred to containers of aerated nutrient solution and equilibrated for three months. Seedlings will be grown in one of three strengths of nutrient solution with 0.1, 0.01 and 0.001 Johnson's solution being the preliminary choices.

Equilibrated seedlings will be exposed to twice weekly simulated mist events of pH 5.6 and 3.0. The simulated mist will be acidified with a mixture of sulfuric, nitric and hydrochloric acid based on cloud data from Henniger Flats, California. Treatments will last for an average of twelve weeks.

The acidified mist and throughfall will be analyzed for conductivity, pH, Ca, K and Mg. At the end of each experiment, plants will be harvested and analyzed for root and shoot biomass and for foliar concentrations of K, Ca and Mg. Rates of cation uptake will be determined from changes in the cation concentrations in the aerated nutrient solutions over one to two day periods.

Deliverables: Interim report: October 1987. Final report: October 1988.

Progress (10/27/86): Seedlings purchased and established in greenhouse. Design and testing of misting system nearing completion.

Project Number: 8

Project Title: Sensitivity of important western conifer species to SO2 and seasonal interaction of acid fog and ozone.

Period of Performance: June 1986-December 1988

Principal Investigators: Dr. W. E. Hogsett
U.S. Environmental Protection Agency
Environmental Research Laboratory-Corvallis
200 S.W. 35th Street
Corvallis, Oregon 97333

Dr. David T. Tingey
U.S. Environmental Protection Agency
Environmental Research Laboratory-Corvallis
200 S.W. 35th Street
Corvallis, Oregon 97333

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $137,000

State/Region of Research: Western U.S. with regard to species being screened.

Scientific Questions Addressed: S.Q. 2.3

Objective: Assess the relative sensitivity of seedlings of important western conifer species to each of two pollutant exposure scenarios likely to occur in the Western U.S.: 1) acid fog/ozone in a seasonal interaction of each pollutant over the year, and 2) SO2 alone.

Project Description:

The relative sensitivities of seedlings of Douglas fir, Ponderosa pine, Lodgepole pine, Western hemlock and Western red cedar to the pollutant regimes listed above will be evaluated through exposures in open-top chambers at the Environmental Research Laboratory-Corvallis. Seedlings and seeds of each species will be obtained from commercial growers and from known seed sources and regions.

Simulated ambient exposure regimes for acid fog, ozone and SO2 will be utilized, reflecting the seasonality of deposition volume, frequency and chemistry for fog, and the seasonality of the frequency and distribution parameters for O3 and SO2 characteristic of selected regions of the West. A range of treatments will be employed with each pollutant, all representative of possible conditions in air quality of the West. This type of exposure regime was recommended by the International Workshop on Standardization of Exposure Systems and Protocol.

Young seedlings (1/0 and 2/0) and emerging seedlings (4-8 weeks) will be assessed over the two year study period (two growing seasons). Measurements of seedling response will include:

1) Weekly assessment of change in stem diameter and height on the same plants over the exposure periods.

2) Change in biomass over exposure period with frequent destructive harvests of seedlings. Measurements include needle, stem, and root dry weight; number and length of branches; needle number by developmental stage; bud number; and bud elongation.

3) Assessment of visible injury including needle injury as % of needle area injured by developmental stage in 5% increments, and the proportion of total number of needles injured or estimate of canopy coverage of injury.

These exposure studies will be coordinated closely with similar work being done for the Western Cooperative by the USFS, Riverside, California.

Deliverables:

Interim report-October 1987. Final report-October 1988. Reports will give 1) a sensitivity ranking of five western conifer species to acid fog/ozone simulated ambient exposure in seasonal interaction based on several growth parameters, and 2) a sensitivity ranking of five western conifer species to SO2 simulated ambient exposure based on several growth variables.

Progress (10/27/86): Four month ozone exposure of all species completed. Acid mist and SO_2 exposure studies are being prepared.

Project Number: 9

Project Title: Testing the sensitivity of five western conifer species to sulfur dioxide alone, and ozone followed by acidic fog.

Period of Performance: June 1986-December 1988

Principal Investigators: Dr. Paul R. Miller
USFS Forest Fire Laboratory
4955 Canyon Crest Drive
Riverside, California 92507

Dr. Paul H. Dunn
USFS Forest Fire Laboratory
4955 Canyon Crest Drive
Riverside, California 92507

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $122,000

State/Region of Research: Western U.S. with regard to species being screened.

Scientific Questions Addressed: S.Q. 2.3

Objective: Assess the relative sensitivity of seedlings of important western conifer species to each of two pollutant exposure scenarios likely to occur in the Western U.S.: 1) acid fog/ozone in a seasonal interaction of each pollutant over the year, and 2) SO2 alone.

Project Description:

The relative sensitivities of seedlings of Douglas fir, Ponderosa pine, White fir, Subalpine fir and Engelmann spruce to the pollutant regimes listed above will be evaluated through exposures in open-top chambers. The SO2 work will be done in facilities at the Riverside Forest Fire Laboratory. The ozone/acid fog work will be done at a facility to be established at Garner Valley in the San Jacinto District of the San Bernardino National Forest. Seedlings and seeds of each species will be obtained from commercial growers and from known seed sources and regions.

Simulated ambient exposure regimes for acid fog, ozone and SO2 will be utilized, reflecting the seasonality of deposition volume, frequency and chemistry for fog, and the seasonality of the frequency and distribution parameters for O3 and SO2 characteristic of selected regions of the West. A range of treatments will be employed with each pollutant, all representative of possible conditions in air quality of the West. This type of exposure regime was recommended by the International Workshop on Standardization of Exposure Systems and Protocol.

Young seedlings (1/0 and 2/0) and emerging seedlings (4-8 weeks) will be assessed over the two year study period (two growing seasons). Measurements of seedling response will include:

1) Assessment of change in stem diameter and height on the same plants over the exposure periods.

2) Change in biomass over exposure period with frequent destructive harvests of seedlings. Measurements include needle, stem, and root dry weight; needle number by developmental stage; bud number; and bud elongation.

3) Assessment of visible injury including needle injury as % of needle area injured by developmental stage in 5% increments, and the proportion of total number of needles injured or estimate of coanopy coverage of injury.

These exposure studies will be coordinated closely with similar work being done for the Western Cooperative by the U.S. Environmental Protection Agency, Environmental Research Laboratory-Corvallis.

Deliverables:

Interim report-October 1987. Final report-October 1988. Reports will give 1) a sensitivity ranking of five western conifer species to acid fog/ozone simulated ambient exposure in seasonal interaction based on several growth parameters, and 2) a sensitivity ranking of five western conifer species to SO2 simulated ambient exposure based on several growth variables.

Progress (10/27/86): Construction of new exposure facilities almost complete in preparation for start of SO_2 exposures.

Project Number: 10

Project Title: Examination of the relationship between spatial patterns of insect/pathogen occurrences in western coniferous forests and patterns of atmospheric deposition: pilot study.

Period of Performance: July 1986-April 1987

Principal Investigator: Mr. Danny Rambo
Environmental Research Laboratory--Corvallis
200 S.W. 35th Street
Corvallis, Oregon 97333

Funding Agency: U.S. Environmental Protection Agency
Environmental Research Laboratory--Corvallis

Funding Level: FY86: $5,000

State/Region of Research: West-wide

Scientific Question Addressed: S.Q. 2.6

Objectives: 1) To inventory existing data sets on pest/pathogen occurrences in western coniferous forests, 2) to perform a preliminary comparison of spatial patterns of pest/pathogen occurrence and atmospheric deposition, and if warranted, 3) prepare a plan for a more comprehensive study.

Project Description:

Tasks:

1) Prepare an inventory of data sets on pest/pathogen occurrences in western forests through literature searches and inquiries to private, state and federal foresters.

2) Evaluate the usefulness of each data set in terms of format, accessibility, comparability with other data sets, and quality assured status.

3) Obtain or produce maps summarizing selected data sets.

4) Manually compare spatial patterns of pest/pathogen occurrences with patterns of atmospheric deposition (information obtained from other Western Cooperative projects).

5) If warranted by results of (4), develop plan for comprehensive study.

Deliverables:

Interim report: November 1986. Included inventory of existing pest/pathogen data bases, evaluation of their usefulness for this study, and maps of pest/pathogen distributions from selected data bases.

Final report: April 1987. Final report will revisit basic assumptions regarding role of pest/pathogens in forest dynamics for the West, then will summarize major sources of western pest/pathogen data and its potential for general correlation studies.

Progress (01/01/87): Interim report complete, final report on schedule.

8.0 Descriptions of 1987 Western Cooperative Research Projects

This section contains a 1-2 page description of each of the thirteen new projects proposed for inclusion in the 1987 research program. They are presented in order by project number.

Project Number: 11

Project Title: Inventory and tracking of atmospheric deposition/forest effects research in the western United States.

Period of Performance: 1987-continuing

Selection of Investigators: Project will be run by Western Cooperative staff.

Approximate Funding Level: FY87 -- $32,000

Scientific Question Addressed: All

Objective: To develop and maintain a computer database of all current and proposed atmospheric deposition/forest effects research projects in the western United States.

Project Description:

The success of the Western Cooperative depends in part upon avoiding unnecessary redundancy with other programs and maximizing opportunities for collaboration. Accomplishing this requires a thorough knowledge of the current and planned research programs on atmospheric deposition and forest effects in the West.

The Western Cooperative has begun to develop a database of non-FRP research projects in the West. The research database will use dBASE III PLUS on an IBM AT. This software allows sorting by any parameter desired including research topic, principal investigator, research locale, and funding agency.

For purposes of the inventory, the West will be divided into four regions. A contract will be established with an individual in each region to perform an initial survey and to provide updates every six months.

The Western Cooperative research database uses the same software and format as a less intensive world-wide database being developed by S&I. This ensures complete compatibility and access for the two groups. The Western Cooperative database may be accessed by any interested person via modum hook-up, floppy disk, or hard copy. The current format of the data base is shown in Table 7.

Table 7. Format of the Western Cooperative research database.

PROGRAM-PROJECT TITLE:
FUNDING AGENCY:
PROJECT OFFICER:
PRINCIPAL INVESTIGATORS
P I INSTITUTION:
PRIME CONTACT-PHONE-ADDRESS:
STATE-REGION-SITE:
SQ-RESEARCH TOPIC:
TYPE:
POLLUTANTS:
MAJOR PARAMETERS:
START-FINISH DATES:
FUNDING AMOUNTS:
DELIVERABLES:
STATUS:
DOCUMENTATION:
DATA BASE EST IN MEGABYTES ASCII:
SI USE:
COMMENTS:
LAST ENTRY DATE:
FILE NUMBER:

Project Number: 12

Project Title: Development of a literature database for appropriate references on atmospheric deposition and forest effects in the western U.S.

Period of Performance: 1987-continuing

Selection of Investigators: Project will be implemented by WCRC staff.

Approximate Funding Level: FY87 -- $16,000

Scientific Question Addressed: All

Objective: To ensure that all relevant information is at hand for development of Cooperative outputs and evaluations of new research initiatives.

Project Description:

It is critical to the success of the Western Copoerative that its staff be fully aware of relevant work performed by other groups. A comprehensive literature database is one step toward that goal. The Western Cooperative literature database will employ dBASE III PLUS on an IBM AT. This software allows entry/storage, search/sort, collation, and formatting subsets of the base for appending directly to written documents or for generating bibliographies on designated topics.

Citations will be acquired through several means including from commercial searches, existing bibliographies, and regular review of current literature. Hard copies of many citations will be kept on file. Citations in the database will have the following format:

Authors: Appel, B. R.; Kothny, E. L.; Hoffer, E. M.; Hidy, G. M.; Wesolo

Date: 1978

Citation: E.S. and T. 12(4):418-425.

Title: Sulfate and nitrate from the California Aerosol Characteriza

Key word: atm. chem. SOX, NOX

Access to the database will be available to any interested person via modum hook-up, floppy disk, or hard copies of limited searches.

S&I is developing a less intensive database of world-wide literature relevant to the FRP. The Western Cooperative database will use the same software and format as the S&I database. The Cooperative will have easy access to relevant citations from studies outside the West while S&I can draw on the Cooperative's database as required.

Project Number: 13

Project Title: Analysis of trends and variability in growth of western forests.

Period of Performance: June 1987-June 1988

Selection of Investigators: Solicitation and review of proposals.

Approximate Funding Level: FY87 -- $250,000

Scientific Questions Addressed: S.Q. 1.1

Objective:

To utilize existing dendrochronological and forest plot remeasurement databases to evaluate natural variability in growth trends of selected western forests and to look for recent deviations in those trends.

Project Description:

The Western Cooperative 1987 research plan emphasizes Policy Question 1. As a result, both of the Scientific Questions derived from Policy Question 1 have 1987 projects devoted to them. Project 13 specifically addresses Scientific Question 1.1: "Are changes in forest condition greater than can be attributed to typical trends and levels of natural variability?"

Answering S.Q. 1.1 for any specific area requires a quantifiable definition of typical trends and natural variability for forest growth in that area. Current trends must be compared to a "normal" background in order to determine whether deviations from normal are occurring. If so, then both non-air pollution and air pollution factors can be evaluated as causes of the deviation.

The Western Cooperative sponsored a recent workshop to discuss the applicability of existing dendrochronological and forest measurement databases to addressing S.Q. 1.1 in the West. The participants determined that extensive and useful databases do exist, including tree ring series at the University of Arizona Laboratory of Tree Ring Research and the University of Washington. Extensive forest plot remeasurement databases are held by the United States Forest Service Forest Inventory Analysis (FIA) and Timber Management. Other institutions hold data from more local monitoring sites.

These databases offer a unique opportunity for addressing S.Q. 1.1. Although the data was not collected specifically for this research, advances in techniques for statistical analysis of such databases have increased their usefulness.

Based on the workshop results, the Cooperative will solicit proposals for studies of selected forested regions in the West designed to: (1) develop a baseline characterization of natural variability in growth trends, and (2) look for deviations of recent growth trends from the norm.

Regions for study need to meet the following criteria in order to maximize the value of the study:

(1) coniferous forest type,

(2) high levels of atmospheric deposition,

(3) good baseline data on tree physiology, stand development, and ecosystem processes, and

(4) existing FIA and dendrochronological databases.

Based on these criteria, potential study areas include:

(1) central Arizona

(2) south-central California

(3) Puget Sound Basin

(4) local (point source) areas of central and northern Rockies

Project Number: 14

Project Title: Development of a comprehensive plan for forest effects research in California.

Period of Performance: September 1986-March 1987

Selection of Investigators: Contract competed and awarded by California Air Resources Board to Dr. Susan Bicknell, Humbolt State.

Approximate Funding Level: FY87-Western Cooperative, $25,000; CARB, $35,000

Scientific Question Addressed: S.Q. 1.1

Objective:

To develop, peer review, and finalize a research plan for the assessment of forest condition and response to atmospheric pollutants in California.

Project Description:

As part of the Acid Deposition Research Program mandated by the Kapiloff Act, the California Air Resources Board (CARB) is starting to develop a forest effects program. The two main questions to be addressed by this program are:

(1) What, if any, are the effects of atmospheric deposition on forests in California?

(2) What are the mechanisms of effect?

Obviously, CARB and the Western Cooperative have many overlapping objectives and collaboration between the two groups will be mutually beneficial. CARB has unsurpassed abilities in air quality monitoring and is preparing to commit substantial effort to forest effects research. The Western Cooperative can offer the experience of the FRP in designing an integrated forest effects program and can contribute financially to work in California. California's high pollution levels, extensive forest resource, and documented damage to some forested areas justify a significant research effort.

A draft research plan is currently being developed with contributions from Humbolt State, CARB, the Western Cooperative, and appropriate technical experts. The plan will be peer reviewed at a February workshop and finalized based on the reviewers' recommendations. The plan will be implemented the following summer. The major topics to be discussed in the plan and at the workshop are:

(1) deposition support for forest effects research,

(2) intensive effects research (site characterization and response monitoring),

(3) extensive effects research (survey),

(4) experimental manipulations,

(5) QA/QC/data management, and

(6) synthesis and integration.

Project Number: 15

Project Title: Evaluation and monitoring of the effects of atmospheric deposition on forest condition in California.

Period of Performance: 1987/continuing

Selection of Investigators: To be determined, but likely a combination of solicitations and sole source.

Approximate Funding Level:

FY87-WCRC, $150,000; California Air Resources Board (CARB), to be determined. Scientific Question Addressed: S.Q. 1.1

Objective: To collaborate with CARB in evaluating the effect of atmospheric pollution on California forests.

Project Description:

The reason for collaboration between CARB and the WCRC and the process for developing a research plan for California are described under Project 14. The CARB research program and the decisions on which contributions the Western Cooperative will make to that program will be developed by Project 14.

Project Number: 16

Project Title: Development and application of remote sensing techniques for the evaluation of forest condition in the western U.S.

Period of Performance: June 1987-June 1988

Selection of Investigators: Solicitation and review of proposals.

Approximate Funding Level: FY87 -- $90,000

Scientific Question Addressed: S.Q. 1.2

Objective: To improve techniques for airborne or satellite remote sensing of forest condition in the West.

Project Description:

The National Vegetation Survey is conducting a pilot test to evaluate the utility of current Thematic Mapper remote sensing systems to detect and quantify forest decline in high elevation boreal forest stands in the eastern United States. A system that would allow rapid wide-scale evaluation of forest condition would obviously be of immense benefit in addressing Scientific Question 1.2.

The WCRC will fund improvement and application of remote sensing techniques in the West. While the results of the NVS eastern study will be of use, differences in species, meteorology, and site conditions require efforts tailored to the West. The Cooperative will solicit proposals to build upon the remote sensing work already ongoing in the West by groups such as NASA, JPL, and several universities.

Two basic approaches are possible and will both be considered. The first is a laboratory effort measuring spectral changes in seedlings exposed to controlled pollutant regimes. This may involve correlation of biochemical changes in seedling foliage with spectral changes. Spectral signatures derived from these studies would then be tested in the field. The WCRC began a pilot study of this type in late October in conjunction with researchers from UC-Davis and Cal. Tech. (Project 23). Spectral reflectance of the canopies of three species of seedlings from the Western Cooperative study at Corvallis were studied, and the results will be used to evaluate future proposals.

The second approach would utilize airborne or satellite spectral data in conjunction with field sites where "ground truth" work on forest condition is conducted. A combination of the two approaches is also possible.

Project Number: 17

Project Title: Monitoring the frequency of exposure of selected western forests to clouds and fog.

Period of Performance: June 1987-June 1988 with options for continuation.

Selection of Investigators: Solicitation and review of proposals.*

Approximate Funding Level: FY87 -- $75,000

Scientific Question Addressed: S.Q. 1.2

Objective: To pilot test a monitoring system for regional estimates of the frequency of forest exposure to clouds and fog.

Project Description:

Clouds and fog have been shown to be important sources of water and chemicals to high elevation and coastal forests of the eastern United States. Chemicals transmitted via clouds are included in several hypotheses regarding damage to eastern spruce-fir forests. In the West, it has been suggested that high elevation forests are at risk from cloud deposition, yet data on cloud chemistry and particularly the frequency with which forests are exposed to clouds is very limited. One of the difficulties in siting cloud chemistry work in some western regions is lack of information on where significant growing-season exposure of forests to clouds may be expected to occur. Additional information on cloud frequency is critical to a valid assessment of the potential impact of this form of deposition.

A number of systems for monitoring visibility are currently operating in the West. It may be possible to adapt some of these systems and their associated technology to monitoring cloud frequency. It may also be possible to couple ground station information with satellite photos of cloud cover and meteorological models to extrapolate between observation points.

This project is intended to be a pilot study limited to one subregion of the West. Collaboration with existing visibility monitoring networks will be strongly encouraged.

Project Number: 18

Project Title: Evaluation of forest response to ambient pollution levels in northwestern Washington/southwestern British Columbia

Period of Performance: June 1987-June 1988/continuing.

Selection of Investigators: Solicitation and review of proposals.

Approximate Funding Level: FY87 -- Western Cooperative, $100,000; NCASI, to be determined.

Scientific Question Addressed: S.Q. 1.2

Objective: To develop an improved estimate of the current and potential effects of ambient levels of atmospheric pollution on Douglas-fir forests in the Puget Sound region.

Project Description:

The Western Cooperative is placing its main emphasis in FY87 on Scientific Questions 1.1 and 1.2. As part of this effort, the Cooperative proposes to co-fund with NCASI an evaluation of Douglas-fir forest response to current levels of pollutants in northwestern Washington and southwestern British Columbia as defined from Tacoma north to Vancouver, B.C., and the Fraser River Valley. Monitoring in this region has shown a wide range of concentrations of sulfur and nitrogen compounds and oxidants. Abbotsford and Chilliwack, British Columbia, have reported hourly average NO_2 values in excess of 90 ppm and hourly average O_3 values greater than 220 ppb. Hourly ozone values at Pack Forest south of Seattle frequently exceed 120 ppb. Cloud water samples collected at a forested site on Mt. Rainier in October 1986 had pHs as low as 3.6. Precipitation samples from other areas in this region often have elevated sulfate and nitrate levels with pHs less than 5.0. While no evidence of forest damage from air pollution exists for this region, levels of some pollutants in some areas may be high enough to influence forest condition.

A recent workshop sponsored by the FRP indentified three basic approaches for evaluating the influence of pollutants on forests:

1. "Correlative" approach -- This approach seeks to establish correlations between observed tree growth or dysfunction symptoms with estimated or measured conditions surrounding the trees, e.g., above and below ground environmental factors, biotic factors, or temporal and spatial gradients of airborne chemicals.

2. "Experimental" approach -- This approach uses controlled manipulations of stress-inducing factors on trees, or on parts of trees, to detect visible or invisible symptoms of injury, changes in growth rates, or changes in physiological processes to assess the relative importance of the stress factors on the growth or health of the tree.

3. "Process-driven model" approach -- The "process-driven model" approach uses various aspects of the "correlative" and "experimental" approaches within a more biologically oriented research strategy or architecture to explain effects of airborne chemicals on growth processes within individual trees.

An appropriate mix of these approaches will be developed into an experimental design for Washington/British Columbia. An improved characterization of pollutant levels will also be an important part of this work and will be supported by Project 19.

Project Number: 19

Project Title: Air quality monitoring in support of Project 18.

Period of Performance: June 1987-June 1988 with options for continuation.

Principal Investigator: Dr. John Bowen
Desert Research Institute
Reno, Nevada 89506

Approximate Funding Level: TBD, but no cost to WCRC for equipment purchase.

Scientific Question Addressed: S.Q. 1.2

Objective: To provide air quality monitoring in support of potential forest effects research in northwestern Washington.

Project Description:

Project 18 consists of an evaluation of the response of forests in northwestern Washington to atmospheric deposition. Obviously, characterization of air quality for that region and especially for the intensive research sites is critical.

The EPA Atmospheric Sciences Research Laboratory (ASRL) competed a contract for establishment of an air quality monitoring/dry deposition research station. A contract was awarded to the Desert Research Institute that included the purchase and setup of the equipment listed in Table 8. The monitoring station will be used in support of the Washington/British Columbia study (Project 18). Investigators submitting a proposal for Project 18 will be requested to include site selection for the monitoring station in their proposal and to integrate use of the station into their work plan.

Table 8. Operational parameters for Washington air quality monitoring site.

Measurement	Averaging Time	Sampling Frequency	Measurement Method	Equipment	Nominal Lower Quantifiable Limit	Manufacturer's Precision
NO	1 hr	Continuous	Chemiluminescence	Monitor Labs 8840 with enhancement	0.5 ppb	±3%
NO_2	1 hr	Continuous	Chemiluminescence	Monitor Labs 8840 with enhancement	1 ppb	±3%
SO_2	1 hr	Continuous	Flame Photometric with seeded H_2	CSI (Meloy) SA 285	0.5 ppb	±3%
O_3	1 hr	Continuous	Ultraviolet absorption	Dasibi 1003 PC	3 ppb	±3%
b_{scat}	1 hr	Continuous	Integrating Nephelometry	MRI 1592 with zero correction	0.1 x 10^{-6} m^{-1}	±10%
Windspeed	1 hr	Continuous	3-cup Anemometer	Weathertronics 2030	0.22 m s^{-1} threshold	±0.07 m s^{-1} or ±1%
Wind direction	1 hr	Continuous	Wind Vane	Weathertronics 2020	NA	±2°
Sigma theta	1 hr	Continuous	Wind Vane	Weathertronics 2020	NA	±2°
Temperature at two levels, ΔT	1 hr	Continuous	Thermister in Aspirated Shield	Weathertronics 4480 Thermistor in Model 8150 Aspirated radiation shield	NA	±0.1°C
Dew Point	1 hr	Continuous	Lithium Chloride Dew Cell	Weathertronics 5320	NA	±0.5°C
Insolation (diffuse)	1 hr	Continuous	Star Pyranometer with Shadow Ring	Weathertronics 3020 with sun shield	NA	
Precipitation	1 hr	Continuous	Tipping Bucket	Weathertronics 6015-B	0.25 mm	0.25 mm
Suspended particle mass in 0 to 2.5 and 2.5 to 10 µm site ranges	1 week	Variable/filter frequency dependent on aerosol loading. Reporting weekly or less.	Virtual Impactor	Sierra-Andersen Model 245 Automatic Dichotomous Sampler	1 µg/m^3	±1 µg/m^3
Wet deposition pH Volume	1 week	1/week	Wet-dry Sampler, pH electrode Balance	Aerochem Metrics Model 301 or Andersen Model APS Markson PT-20 pH Meter Ohaus 11190 Balance	NA 1 cm^3	±0.1 pH ±1 cm^3

Project Number: 20

Project Title: Comparison of the response of mature branches, seedlings, and grafts of Western Conifers to air pollution.

Period of Performance: May 1987-December 1989

Selection of Investigators: Competition.

Approximate Funding Level: FY87 -- Western Cooperative, $95,000; NCASI, to be determined.

Scientific Question Addressed: S.Q. 2.3

Objective: To evaluate the differential response to air pollution of seedlings, grafts, and branches of a single species of western conifer.

Project Description:

Much of the experimental work currently being conducted by the FRP involves the manipulation of seedlings. This approach has been adopted because of the lack of tested techniques for whole tree exposure and the difficulty and expense of achieving sufficient replication of exposures of trees older than seedlings. However, a recent workshop convened by the FRP concluded that results from studies of seedlings have qualitative value, but very limited quantitative value for the prediction of pollution effects on mature trees. It is apparent that work with mature trees must be conducted to complement the ongoing work with seedlings. Comparisons of the response to air pollution of seedlings with the response of mature tissue is needed for the evaluation of the results of the seedling exposures.

This project will develop and/or test hardware and protocols for controlling the exposure of attached branches of mature conifers to atmospheric pollutants. The techniques will be applied in an experiment designed to compare the response of individual branches to ambient and filtered air. As part of the same experiment, the response of branches on mature trees will be compared to the responses of seedlings and grafts.

Project Number: 21

Project Title: Air pollutant exposure of mature forest trees: methodology development and performance evaluation.

Period of Performance: October 1986-September 1989

Selection of Investigators:

Proposals previously solicited and reviewed by Southern Commercial Forest Research Cooperative. G. E. Taylor of Oak Ridge National Laboratory selected as Principal Investigator along with seven co-PIs.

Approximate Funding Level:

FY87 -- Western Cooperative, $50,000; Southern Commercial Cooperative, $550,000+. Undetermined support from Spruce-Fir Cooperative.

Scientific Question Addressed: S.Q. 2.3

Objective: To develop and test a range of methodologies for the field exposure of mature forest trees to wet and dry deposition of airborne chemicals.

Project Description:

Although pronounced differences have been observed between the physiological characteristics of juvenile and mature trees, the Forest Response Program is relying heavily on the use of seedlings in its manipulative experiments. Mature trees or forest stands are not as amenable to experimental manipulation as are seedlings. However, the FRP has a pressing need to develop whole tree exposure methodologies in order to directly assess the impact of pollutants on mature trees and to evaluate the degree to which seedling response data may be extrapolated to mature trees.

The Southern Commercial Forest Research Cooperative has initiated development of appropriate methodologies in conjunction with Oak Ridge National Laboratory and other research groups. Because the results of the work will be of use to the entire FRP, the Western Cooperative is proposing to co-fund this effort.

The essential features of the proposed research are: (1) the incorporation of multidisciplinary expertise (forest meteorology, engineering, plant physiology, instrumentation and controls, and fluid dynamics); (2) stepwise logical testing and development of procedures to evaluate performance, beginning with wind tunnel experimentation and progressing to field validation; (3) development of both exclusion and addition capabilities for dry deposition, ranging from open-air to partial-enclosure methodologies; (4) development of methodologies to exclude wet deposition; (5) utilization of methodologies that provide both uniform and nonuniform concentration profiles within the crown; and (6) evaluation of performance using a specific suite of criteria that

include the degree of control over pollutant chemistry and foliar deposition in the crown, modification of the meteorological conditions in the crown, and inadvertent changes in the tree's physiological status.

Project Number: 22

Project Title: Spectral characteristics of conifer species exposed to simulated pollutant regimes.

Period of Performance: October 1986-September 1987

Selection of Investigators: Dr. Susan L. Ustin
Department of Botany
University of California
Davis, California 95616

Dr. Brian Curtiss
Department of Geology
California Institute of Technology
Pasadena, California 91125

Approximate Funding Level: FY87 -- $10,000

Scientific Question Addressed: S.Q. 2.3

Objective: To determine if the spectral reflectances of seedlings of three conifers are altered by exposure of the seedlings to O_3, SO_2, and acid mist.

Project Description:

Seedlings of Douglas fir, ponderosa pine, and lodgepole pine are being exposed to simulated ambient regimes of acid mist, SO_2, and O_3 as part of Project 8. Changes in the spectral reflectances of these species resulting from exposure to pollutants might be used in the development of techniques for the remote sensing of forest condition.

The reflectance spectra of treated and control seedling canopies are being measured by an instrument called PIDAS (Portable Intelligent Display and Analysis Spectrometer). PIDAS is a backpack instrument which makes reflectance measurements in the visible using 1 nm bands and in near-infrared using 5 nm bands. Spectral changes correlating with pollutant exposure will be analyzed in terms of possible physical and physiological causes. The results will also be interpreted in terms of the potential usefulness of remote sensing as a technique for evaluating forest condition.

Project Number: 23

Project Title: Solicitation of proposals to address Scientific Questions 2.1-2.6 as appropriate to the western U.S.

Period of Performance: For funded proposals, April 1987-April 1987

Selection of Investigators: Solicitation and review of proposals.

Approximate Funding Level: FY87 -- $100,000

Scientific Question Addressed: To be determined.

Objective: To determine which of S.Q.s 2.1-2.6 require further study in the West by soliciting proposals for research on any of these questions.

Project Description:

With the exception of S.Q. 2.3, the Western Cooperative's proposed FY87 work on S.Q.s 2.1-2.6 emphasizes obtaining existing information and determining from that whether those questions need to be addressed further in order to meet the Cooperative's objectives. To augment this process, the Cooperative proposes to ask the western scientific community which Scientific Questions should be investigated further in the context of the general FRP strategy.

Proposals will be evaluated under the following criteria:

1. justification of the proposed research in terms of integration with the Western Cooperative program;

2. existing evidence that the proposed research addresses a problem which is significant in the West; and

3. technical quality and feasibility of proposal.

The Cooperative may elect not to fund any proposals if none of them are appropriate. If a number of good proposals are received, the ideas will be used in developing future annual plans.

9.0 Budgets

Table 9 shows the proposed FY87 budget for all Forest Response Program components. Table 10 gives the Western Cooperative FY86 budget while Tables 11 and 12 show allocations for the proposed Western Cooperative FY87 budget. The FY87 budget figures are the most current estimates, but all are subject to change during the fiscal year. The federal fiscal year begins October 1 and ends September 30.

Several projects (7, 11, 12, 23) address multiple Scientific Questions. In Tables 10 and 11, the funds for these projects are distributed evenly among the Scientific Questions to which they apply.

Table 9. Proposed FY87 Forest Response Program budget allocations ($1000s).

FRP Component	Proposed Appropriation
Spruce-Fir	4236
Southern Commercial	4922
Eastern Hardwoods	1770
Western Conifers	1443
Vegetation Survey	1354
Atmospheric Exposure	3035
QA/QC	600
S&I	980
National Management	104
Total	18444

Table 10. Western Cooperative FY86 budget allocations

Scientific Question	Project #	Committed ($1000)	% Total Committed
1.1	-	(0)	± 0
1.2	1	60	
	2	5	
	3	25	
	4	90	
	5	8	
	6	55	
	Total S.Q. 1.2	(243)	38%
2.1	7	(25)	4%
2.2	7	(25)	4%
2.3	8	137	
	9	203	
	Total S.Q. 2.3	(340)	53%
2.4	-	0	0
2.5	-	0	0
2.6	10	(5)	1%
Lab Overhead[1]	-	0	0
Program Management[2]	-	0	0
Carry-over to FY87[3]	-	212	
Totals		850	100%

[1] No lab overhead was assessed against the Western Coop in FY86.

[2] Western Coop management costs were not separate from the overall forest effects budget in FY86.

[3] Funds were banked in a variety of ways.

Table 11. FY87 Western Cooperative research budget. All numbers are $1000s.

Available Funds:

FY86 Carryover	212
FY87 EPA	843
FY87 USFS	600
Total	1613

FY87 Estimated Overhead -- 174 (10% for EPA funds, 15% for USFS funds)

Net Total 1481

Scientific Question	Project #	Status	Requested ($ K)	% Total Allocations	% Total for S.Q.s
1.1	11	New	4		
	12	New	2		
	13	New	250		
	14	New	25		
	15	New	150		
		Total S.Q. 1.1	431	29	32
1.2	5	Continuing	40		
	11	New	4		
	12	New	2		
	16	New	90		
	17	New	75		
	18	New	100		
	19	New	90		
		Total S.Q. 1.2	401	28	30
2.1	7	Continuing	25		
	11	New	4		
	12	New	2		
	23	New	16		
		Total S.Q. 2.1	47	3	3
2.2	7	Continuing	25		
	11	New	4		
	12	New	2		
	23	New	16		
		Total S.Q. 2.2	47	3	3

Table 11 (continued)

Scientific Question	Project #	Status	Requested ($ K)	% Total Allocations	% Total for S.Q.s
2.3	8	Continuing	178		
	9	Continuing	0		
	11	New	4		
	12	New	2		
	20	New	95		
	21	New	50		
	22	New	10		
	23	New	16		
		Total S.Q. 2.3	355	24	26
2.4	11	New	4		
	12	New	2		
	23	New	16		
		Total S.Q. 2.4	22	1	2
2.5	11	New	4		
	12	New	2		
	23	New	16		
		Total S.Q. 2.5	22	1	2
2.6	10	Continuing	5		
	11	New	4		
	12	New	2		
	23	New	16		
		Total S.Q. 2.6	27	2	2
		Total All S.Q.'s	1352		(100)
Program Management		Salaries (Olson, 1/4 Rambo, 1/2 Birch)	45		
		Salary overhead	45		
		Travel	39		
		Total Management	129	9	-
		Total Allocations	1481		

Table 12. Western Cooperative FY87 budget: breakdown by Scientific Questions within new initiatives and continuations.

A. FY 87 New Initiatives

S.Q.	$1000s	% of New Initiatives
1.1	431	40
1.2	361	34
2.1	22	2
2.2	22	2
2.3	177	16
2.4	22	2
2.5	22	2
2.6	22	2
Total	1084	100

B. FY87 Continuations

S.Q.	$1000s	% of Continuations
1.1	0	0
1.2	40	15
2.1	25	9
2.2	25	9
2.3	178	66
2.4	0	0
2.5	0	0
2.6	5	1
Total	273	100

10.0 Forest Response Program Management

Federal Management Group

Dr. Gary Foley
U.S. Environmental Protection Agency
401 M. Street, S.W.
Washington, D.C. 20460
FTS 382-5982
(202)382-5982

Dr. Ronald D. Lindmark, Director
Forest Environment Research
USDA Forest Service
P.O. Box 2417
Washington, D.C. 20013
(703)235-1071

Dr. Raymond G. Wilhour, Chief
Air Branch
Environmental Research Lab - Corvallis
U.S. Environmental Protection Agency
200 S.W. 35th Street
Corvallis, OR 97333
FTS 420-4634
(503)757-4634

Dr. Charles W. Philpot
Associate Deputy Chief
Forest Fire and Atmospheric Science Research
USDA Forest Service
P.O. Box 2417, Room 610-A RPE
Washington, D.C. 20013
FTS 235-1767
(202)447-4507

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National Program Management

Ann Carey
National Program Manager
Forest Response Program
USDA Forest Service
P.O. Box 2417, Room 605
Washington, D.C. 20013
FTS 235-8195

Dr. Anthony C. Janetos
Deputy National Program Manager
Forest Response Program
U.S. Environmental Protection Agency
401 M. Street, S.W. (RD-676)
Washington, D.C. 20460
FTS 382-5791
(202)382-5791

Dr. Roger Blair
Forest Team Leader
Forest Response Program
Environmental Research Laboratory - Corvallis
U.S. Environmental Protection Agency
200 S.W. 35th Street
Corvallis, OR 97333

FTS 420-4662
(503)757-4662

Dr. Ross Kiester
Synthesis & Integration Team Leader
Forest Response Program
Environmental Research Laboratory - Corvallis
U.S. Environmental Protection Agency
200 S.W. 35th Street
Corvallis, OR 97333

FTS 420-4677
(503)757-4677

John Duff Bailey
Acting QA Project Leader
Forest Response Program
Environmental Research Lab - Corvallis
200 S.W. 35th Street
Corvallis, OR 97333

FTS 420-4324
(503)757-4324

- -

Cooperative Managers

Dr. Ann M. Bartuska, Manager
Southern Commercial Research Cooperative
Acid Deposition Program
North Carolina State University
1509 Varsity Drive
Raleigh, NC 27606

(919)737-3520

Dr. Gerald Hertel, Manager
Spruce-Fir Research Cooperative
N.E. Forest Experiment Station
USDA Forest Service
370 Reed Road
Broomall, PA 19008

FTS 489-3011
(215)461-3011

Max W. McFadden, Manager
Eastern Hardwoods Research Cooperative
USDA Forest Service
370 Reed Road
Broomall, PA 19008

FTS 489-3118
(215)461-3118

Richard K. Olson, Manager
Western Conifers Research Cooperative
Environmental Research Lab - Corvallis
200 S.W. 35th Street
Corvallis, OR 97333

FTS 420-4600
(503)757-4600

Dr. Ronald Bradow, Manager
Atmospheric Exposure Cooperative
Environmental Sciences Research Lab
MD-57
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

FTS 629-5179
(919)541-5179

Joseph Barnard, Manager
Vegetation Survey
USDA Forest Service
P.O. Box 12254
Research Triangle Park, NC 27709

FTS 629-1105
(919)541-1105

- -

Western Cooperative QA Specialist

Steve Cline
QA Specialist
Forest Response Program
Environmental Research Lab - Corvallis
200 S.W. 35th Street
Corvallis, OR 97333

FTS 420-4600
(503)757-4600

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NCASI Liaison to Western Cooperative

Dr. George Ice
NCASI
P.O. Box 458
Corvallis, OR 97339

(503)754-2015

Appendix A

Abbreviated Resumes of Western Cooperative Staff

ABBREVIATED RESUME

Richard Kenneth Olson

Current address

29780 Main Street
Shedd, Oregon 97377

Born: 21 October, 1952
Sidney, New York

Education

Dartmouth College, Hanover, N.H., 1970-1973, B.A. (Biology)
University of North Carolina, Chapel Hill, N.C., 1973-1975, M.A. (Ecology)

Employment

Instructor, Small Scale Agriculture, Lebanon College, Lebanon, N.H., 1978-1982

Research Associate, Department of Biological Sciences, Dartmouth College, Hanover, N.H., 1977-1984

Research Associate, Department of Botany, University of Wyoming, Laramie, Wyoming, 1984-1985

Senior Scientist, Northrop Services, Inc., Corvallis, Oregon, 1985-present

Publications

Blank, J. L., R. K. Olson, and P. M. Vitousek. 1980. Nutrient uptake by a diverse spring ephemeral community. Oecologia 47(1):96-98.

Olson, R. K., W. A. Reiners, C. S. Cronan, and G. E. Lang. 1981. The chemistry and flux of throughfall and stemflow in subalpine balsam fir forests. Holarctic Ecology 4:291-300.

Lovett, G. M., W. A. Reiners, and R. K. Olson. 1982. Cloud droplet deposition in subalpine balsam fir forests: hydrologic and chemical inputs. Science 218:1303-1304.

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Baldwin, I. T., R. K. Olson, and W. A. Reiners. 1983. Protein binding phenolics and the inhibition of nitrification in subalpine balsam fir soils. Soil Biology and Biochemistry 15:419-423.

Reiners, W. A., and R. K. Olson. 1984. Effects of canopy components on throughfall chemistry: an experimental analysis. Oecologia 63:320-330.

Olson, R. K., and W. A. Reiners. 1985. Trajectory analysis of forest canopy effects on chemical flux in throughfall. Biogeochemistry 1:361-373.

Reiners, W. A., R. K. Olson, L. Howard, and D. A. Schaefer. 1986. Ion migration from interiors to outer surfaces of balsam fir needles during dry, interstorm periods. Environmental and Experimental Botany 26:227-231.

Olson, R. K., and W. A. Reiners. Plant uptake and the control of potassium losses from balsam fir forests. (in preparation)

ABBREVIATED RESUME

Danny L. Rambo

Current Address

1126 N.W. 29th Street
Corvallis, Oregon 97330

Born: 3 September 1947
Hale Center, Texas

Education

Wayland College, Texas, 1971, B.S. (Biology and Chemistry)

Oregon State University, Corvallis, Oregon, 1981, M.S. (Environmental Science)

Employment

U.S. Army, 1971-1974

Teaching Assistant, Oregon State University, Corvallis, Oregon, 1974-1977

Forest Scientist, Northrop Services, Inc., Corvallis, Oregon, 1978-present

Publications

Glass, N. R., D. E. Arnold, J. N. Galloway, G. R. Hendry, J. J. Lee, W. W. McFee, S. A. Norton, C. F. Powers, D. L. Rambo, and C. L. Shofield. 1982. Effects of acid precipitation. Environ. Sci. Technol. 16:162A-169A.

Powers, C. F., and D. L. Rambo. 1981. The occurrence of acid precipitation on the west coast of the United States. Environmental Monitoring and Assessment 1:93-105.

Glass, N. R., C. F. Powers, J. Lee, D. L. Rambo, and D. O'Guinn. 1980. The sensitivity of the United States environment to acid precipitation. Proc. of International Conference on the Ecological Impact of Acid Precipitation. Sanford, Norway. SNSF Project.